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A HUMAN FACTORS ENGINEERING ASSESSMENT OF AN ANATOMICALLY CONFORMING AIRCREW BODY ARMOR SYSTEM

Bernard M. Corona, et al

Human Engineering Laboratory
Aberdeen Proving Ground, Maryland

June 1973

U. S. ARMY

Technical Memorandum 9-73

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ABERDEEN PROVING GROUND, MARYLAND

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An anatomically conforming, four-size, aircrew body armor (ACBA) system, developed by US Army Natick Laboratories, was assessed to determine its compatibility with Army aviator body sizes, flight task requirements and aircrew station geometry. As a base for all comparisons the standard three-size, aircrew body armor (SBA) system was used. Where possible an attempt was made to integrate and utilize elements of the HEL Armor System Development/Evaluation Guideline, TM 18-69.

Thirty enlisted men and six officer pilots were used as subjects. As a result of this HFE assessment it has been determined that the ACBA system was not suitable as proposed, the SBA system has serious shortcomings, and the HEL TM 18-69 cannot be utilized for the development or evaluation of body-worn armor systems.

With modifications the ACBA can be a suitable body armor system for Army aircrewmen. It can provide the following: increased body area coverage, improved fit for the design range of 5th through 95th percentile, improved compatibility with aircraft restraint systems, and improved compatibility with aircrew station geometry, environmental clothing/body-worn survival equipment.

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An anatomically conforming, four-size, aircrew body armor (ACBA) system, developed by US Army Natick Laboratories, was assessed to determine its compatibility with Army aviator body sizes, flight task requirements and aircrew station geometry. As a base for all comparisons the standard three-size, aircrew body armor (SBA) system was used. Where possible an attempt was made to integrate and utilize elements of the HEL Armor System Development/Evaluation Guideline, TM 18-69.

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A HUMAN FACTORS ENGINEERING ASSESSMENT
OF AN ANATOMICALLY CONFORMING AIRCREW BODY ARMOR SYSTEM

INTRODUCTION

The US Army Natick Laboratories (NLABS) requested that the US Army Human Engineering Laboratory (HEL) perform an in depth HFE analysis of an anatomically-configured aircrew body armor developed under NLABS Contract No. DA 19-129-AMC-1002(N). This report presents a detailed HFE assessment of a four-sized anatomically-configured body armor. This work was accomplished under NLABS Project No. 1F 164 204D 154 01 010; Human Factors Engineering System Analysis of Aircrew Armor.

The study objective was to conduct a detailed HFE assessment of the proposed system as compared to the Standard Aircrew Small Arms Protective Armor with respect to the following: Dimensional Suitability, Mission Interface, Amount of Protection Afforded, Effects on Operator Performance, and Effects on Aircraft Performance for the Aircrew Stations for each of five aircraft.

For purposes of clarity, the terms used to designate each of the five major tasks, shown in Figure 1, are briefly defined as follows:

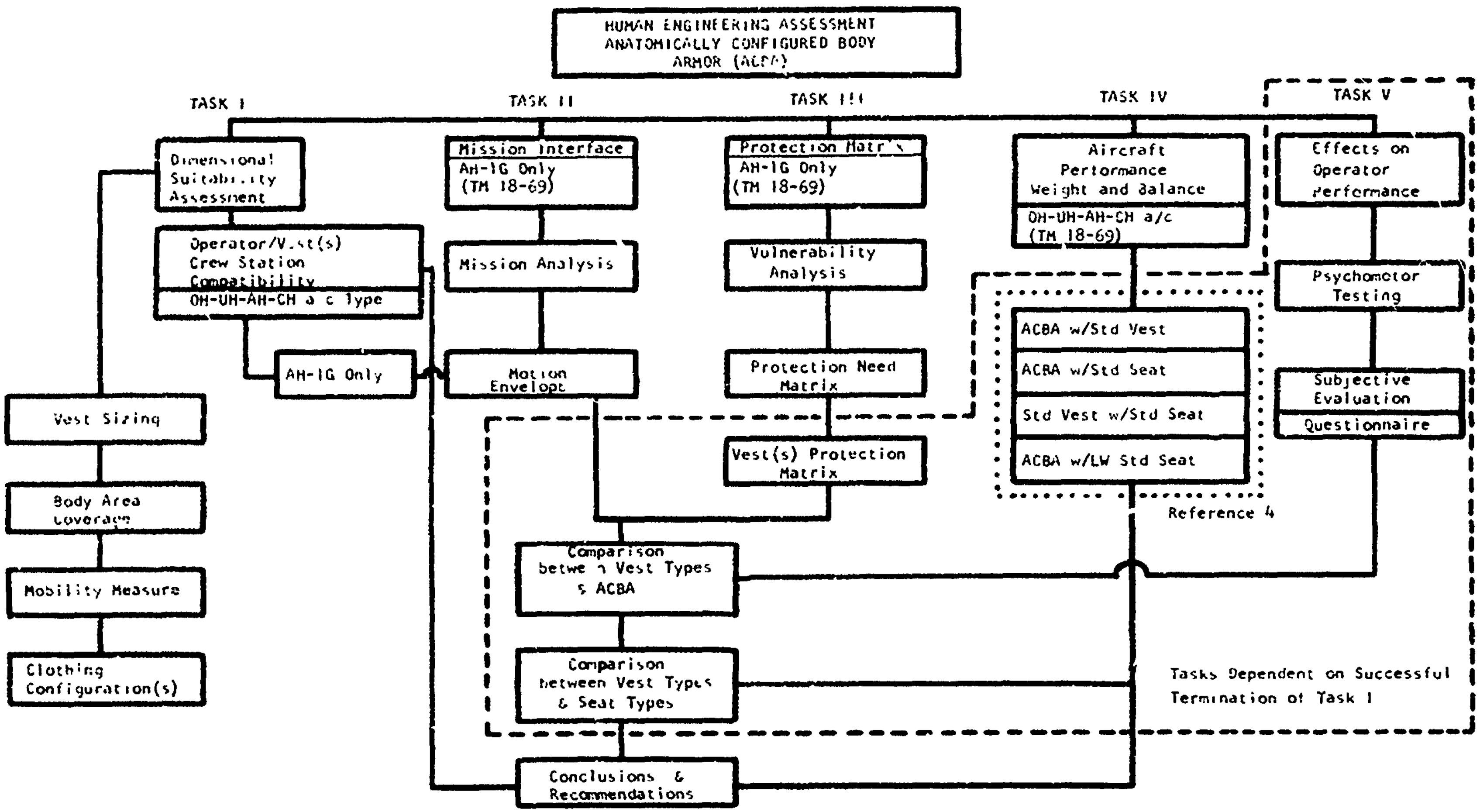
TASK I - Dimensional Suitability

Dimensional suitability is defined as those physical measures which determine the interface between the operator (percentile sizes) and the armored vest(s) (vest sizing system); the operator/vest combination with the crew station (seat/seat system); and the operator/vest/crew station interface with the overall cockpit configuration.

This task provided an assessment of the Anatomically-Configured Body Armor compatibility with selected army aircraft cockpits (5 types: Observation - OH-6, OH-58; Utility - UH-1; Attack - AH-1; and Cargo - CH-47 or CH-54). The aircraft cockpits selected were evaluated using subjects clothed and equipped in the current operational fashion for HOT-WET and HOT-DRY climatic conditions.

TASK II - Mission Interface

The mission interface refers to the manner in which the effects of body armor are systematically related to the operator's performance of the various tasks required throughout a specific mission profile. A mission analysis for the AH-1G was performed to provide input data for exercising the appropriate section of TM 18-69; specifically, the derivation of the motion envelope development section.


HUMAN ENGINEERING ASSESSMENT ANATOMICALLY CONFIGURED BODY ARMOR (ACBA)
TASK I
TASK II
TASK III
TASK IV
TASK V
Dimensional Suitability Assessment
Operator/Vest(s) Crew Station Compatibility
OH-UH-AH-CH a/c Type
AH-1G Only
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Body Area Coverage
Mobility Measure
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Effects on Operator Performance
Psychomotor Testing
Subjective Evaluation
Questionnaire
Comparison between Vest Types & ACBA
Comparison between Vest Types & Seat Types
Conclusions & Recommendations
Tasks Dependent on Successful Termination of Task I

FIGURE 1.

TASK III - Protection Need Matrix

Using the photographic technique described in TM 18-69, a vulnerability analysis of the AH-1G was performed to provide data input for the "protection need matrix." This provided the protection level inherent in the total aircraft system (aircraft structure, subsystem components, component armor and armored seats).

TASK IV - Aircraft Performance/Weight and Balance

Aircraft performance/weight and balance refers to the addition or subtraction of weight in the aircraft system (body armor in this case) which affects center-of-gravity (CG) and gross weight computations.

TASK V - Effects on Operator Performance

The measure obtained in Tasks I and II provide only an index of the physical limitations imposed on the operator; they allow no evaluation of the effects of these limitations on performance over time. Therefore, the armored vest configurations/weight were investigated to determine their impact on the performance of selected aircrew/pilot tasks.

Figure 1 graphically illustrates the relationship between the various tasks. Task I is both the initial and key area for the whole assessment. The body armor system being assessed must be dimensionally suitable and of a configuration which will allow the operator to function at the aircrew station. If neither of these basic evaluative criteria can be satisfied, the system under consideration cannot be functionally included in the subsequent tasks (Fig. 1, dashed area).

The aircrew body armor system assessed in this report could not successfully meet the two basic criteria. Therefore, it was not possible to integrate the ACBA system with Tasks II through V. However, Tasks II, III and IV were completed up to the point where the assessed system was to be included. Task V was initiated but limited to observation of subjects performing standard operational tasks including doffing-donning, ingress-egress, cyclic control movement, etc. Due to time restraints and the nonavailability of a suitably modified body armor system, the program was terminated.

EXERCISING THE HEL ARMOR SYSTEMS DEVELOPMENT/EVALUATION GUIDELINE TASKS II, III & IV

One of the principal reasons for this HFE evaluation of ACBA was Natick Laboratories' desire to exercise the HEL armor systems model as it relates to the evaluation of aircrewman armored vests. The original model, as reported in HEL Technical Memorandum 18-69 (5), does not explicitly contain methodology for the analysis of the relative efficiency of body armor systems. Rather, the model addresses itself specifically toward the evaluation of aircrew protection needs as a function of: (a) existing protection afforded by aircraft structural components, (b) addition of seat armor, and (c) addition of armor material to the aircraft skin. The only area in which the model can directly provide data relevant to the addition of body armor is that of the aircraft weight/balance performance matrix, Task IV. Therefore, disregarding numerical sequence, this report next discusses the work done on Task IV.

TASK IV

Basically, the product of this section of the armor systems model is a weight/balance matrix - for a given aircraft - which indicates the amount of armor material which can be added at any given location on the aircraft without shifting the aircraft CG beyond critical limits. The aircraft chosen for the HFE evaluation of ACBA was the AH-1G attack helicopter. Unfortunately, the Army Systems Guideline was found to be too general for application to this type of aircraft in that the methodology failed to consider the problems involved with multiple armament capability. As part of this study, therefore, it was necessary to develop additional methodology and improved criteria to insure that under all armament configurations - in both normal and abnormal loading situations - the helicopter's weight and balance limits would not be exceeded by the addition of X amount of armor at Y location. A detailed description of this work published as HEL Technical Memorandum 14-71 (4) was furnished to Natick Laboratories. With respect to the overall evaluation of ACBA vs SBA the most important point which emerged in TM 14-71 is:

"As a base for the investigation, an AH-1G helicopter was selected as being typical; however, the matrix values generated cannot be summarily applied to all AH-1G helicopters. Variations in weights and balances between helicopters in a production lot, even though insignificant when compared to the helicopter's basic weight, can overshadow and significantly shift the matrix values." (p. 11).

More specifically, Cvitan (3) states:

"The basic operating weights are constant for all helicopters of the same model. These weights normally vary $\pm$ 50 pounds. Actual weights are determined by weighing the aircraft on delivery (p. 5)." Since this $\pm$ 50 pound variation in aircraft basic weight far exceeds differences between SBA and ACBA, the remainder of the subtasks in this section were terminated as regards weight. Comparisons between vest types and standard/lightweight standard aircrew seats were made from the standpoint of crew station compatibility however, and the results of these comparisons are reported under Task I - Dimensional Suitability.

TASKS II and III

These task areas are reported under the same heading because of their integral relationship in the armor systems model. Strictly speaking, all Task II subsections must be accomplished prior to their input into Task III. Again, using the AH-1G attack helicopter as the representative aircraft, Task II was initiated through the development of a detailed mission analysis (contained in Ref. 5). Utilizing the techniques and methodology outlined in Phase II of TM 18-69, a motion envelope was constructed (Appendix A) and used as an input for Task III, development of the protection need matrix. Combining motion envelope manikins, a scale model of the AH-1G, and the photographic methods of TM 18-69, a vulnerability analysis was performed and the result translated into a protection need matrix (Appendix B). At this time, no additional work was initiated for this task due to the nonavailability of finalized ACBA plates and carriers. It is worthwhile, however, to discuss the problems inherent in any attempt to exercise this phase of the Armor Guideline with respect to body armor. Consider first, the simplest case in which effects of adding a single type of aircrew body armor are to be determined. Given a mission analysis, one would ordinarily photograph the crewmember(s) as they performed these tasks and thus obtain the motion envelope needed in subsequent phases. With the crewmember wearing an armored vest, however, a procedure which is relatively simple conceptually becomes an extremely difficult technological problem under the methodological constraints imposed by the Armor Guideline Model. What is actually required now is the determination of two motion envelopes -- one for the overall body and one for the armored vest itself. Moreover, it seems apparent that the development of a vest envelope would provide a valid input to the vulnerability analysis only if based on an exhaustive mission/task performance evaluation. That is to say, that while the overall motion envelope represents a reliable probability statement of the pilots location in the crew station during a mission, the location of his armored vest relative to seat armor and passive aircraft protection could fluctuate within wide limits. Thus, in the vulnerability analysis where the aircraft is viewed as being hit from a number of directions, it is much easier to determine the probability of penetrating the overall motion envelope than to ascertain whether or not the vest was in a position - at that instant - to stop the round.

Given the problems involved in determining and utilizing a motion envelope for a single vest, the difficulties involved in comparing two vest types become obvious. The most serious problem is one of accuracy in detecting differences of vest area coverage which are apt to be expressed in terms of a few square inches only.

In summary, there are probably a number of techniques which could be developed for critical analysis of small differences in area coverages of armored vests. The HEL Armor Systems Development/Evaluation Guideline does not, however, appear to us at this time capable of providing accurate comparative data commensurate with the potential effort required to exercise the model. Rather, the Guideline should be applied to the contexts for which it was originally developed, i.e., addition of seat or aircraft armor to existing or prototype aircraft.

TASK I - DIMENSIONAL SUITABILITY

Physical Characteristics of Aircrew Body Armor Systems

The Anatomically Configured Aircrew Body Armor (ACBA) is a four-size system consisting of the following sizes:

a. Medium Regular - Front and back plates with canvas duck carrier.

b. Medium Long - Front and back plates with canvas duck carrier.

c. Large Regular - Front and back plates with canvas duck carrier.

d. Large Long - Front and back plates with canvas duck carrier.

Fitting criteria, front and back plate dimensions for the four-sizes are included in Tables 1 and 3. The system was provided in two weights, one weight equivalent to aluminum oxide (AL_2O_3) and one set equivalent to boron carbide (B_4C). Additional physical characteristics including plate surface area, weight and fully assembled dimensions (plates w/carrier) are contained in Tables 1 and 2; Figures 2 through 6.

TABLE 1

FITTING TABLE FOR ANATOMICALLY CONFIGURED AIRCREW BODY ARMOR SYSTEM

Size	Waist Front Seated (in.)		Chest Breadth (in.)		Chest Circumference* (in)	
	From	To	From	To	From	To
Medium-Regular	12.0	14.5	10.5	12.0	33.0	37.0
Large-Regular	12.0	14.5	12.0	13.5	37.0	41.0
Medium-Long	14.5	17.0	11.5	13.0	36.0	40.0
Large-Long	14.5	17.0	13.0	14.5	40.0	45.0

*Alternate to Chest Breadth

TABLE 2

FITTING TABLE FOR STANDARD AIRCREW BODY ARMOR SYSTEM

Size	Percentile	Stature	Shoulder Hgt. Sitting	Bideltoid Dia Sitting	Chest Depth Sitting
Short	1 thru 25	63.0 thru 67.0	to 23.0	to 17.6	to 8.4
Regular	26 thru 80	67.1 thru 71.0	23.1 thru 24.7	17.6 thru 19.0	8.4 thru 10.0
Long	81 thru 99	71.1 thru 75.0	24.8 thru 26.4	19.1 on	10.1 on

TABLE 3

PHYSICAL CHARACTERISTICS OF ANATOMICALLY CONFIGURED AIRCREW BODY ARMOR SYSTEMS

ITEM		WEIGHT IN OUNCES							DIMENSION IN INCHES					AREA IN SQ INCHES		
SIZE	MAT.	P	C	P+C	FV	P+C +FV	SS	P+C +SS	PWC	PWC +C	PWW +C	PL	PL +C	UH	LH	TOTAL AREA
Medium-Regular	AL_2O_3	192	46	238	128	366	NA	NA	9.0	9.2	13.5	14.5	14.6	81.3	122.9	204.2
	B4C	156.8	46	202.8	128	330.8	NA	NA						78.2	129.0	207.2
Medium-Long	AL_2O_3	244.8	50	294.8	128	422.8	NA	NA	9.2	9.5	14.3	17.1	17.3	98.5	156.6	255.1
	B4C	198.4	50	248.4	128	376.4	NA	NA						95.2	159.4	254.6
Large-Regular	AL_2O_3	212.8	48	260.8	128	388.8	NA	NA	9.6	9.9	15.1	14.1	14.3	85.0	130.8	215.8
	B4C	171.2	48	219.2	128	347.2	NA	NA						85.3	130.8	216.1
Large-Long	AL_2O_3	264.0	54	318	128	466	NA	NA	9.7	10.2	15.9	16.5	16.7	99.2	173.8	273.0
	B4C	212.8	54	266.8	128	394.8	NA	NA						100.3	172.0	272.3

STANDARD AIRCREW BODY ARMOR

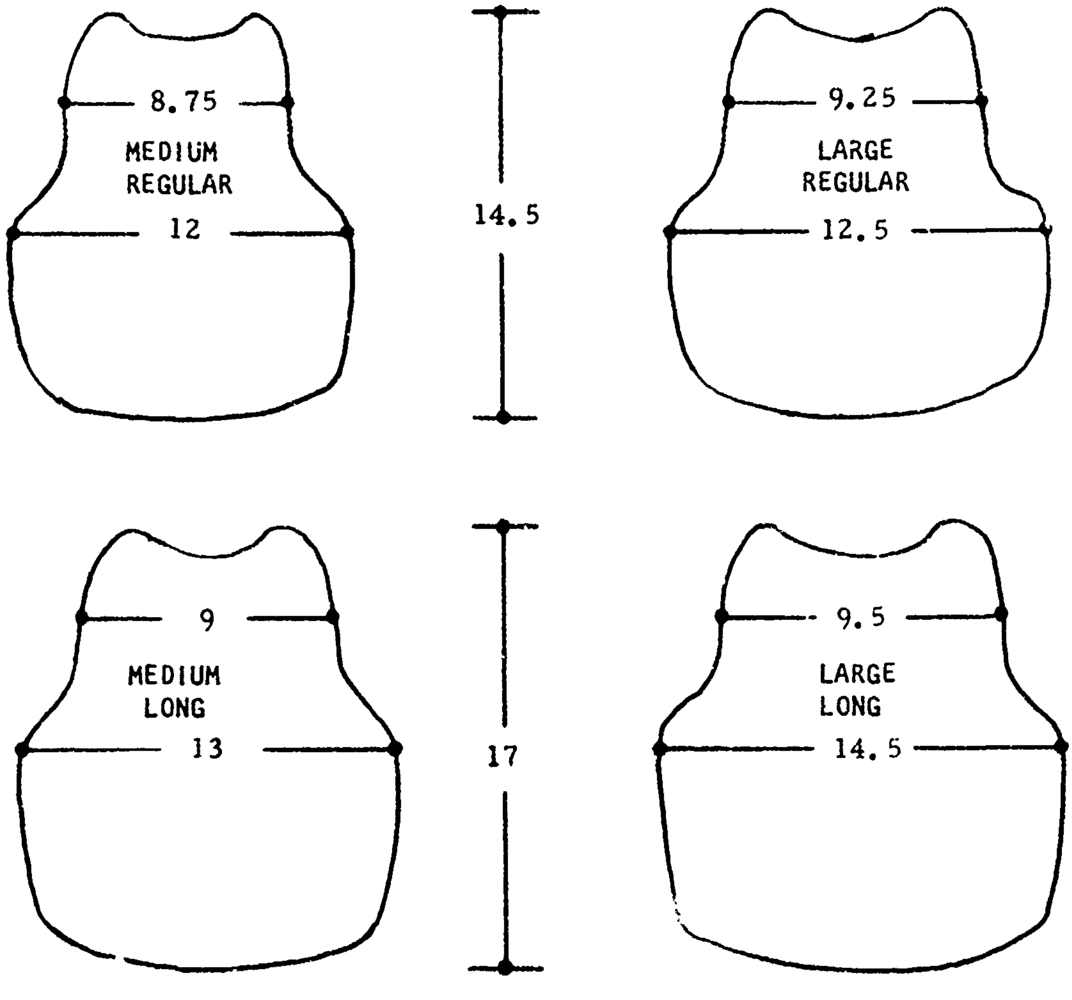
ITEM		WEIGHT IN OUNCES							DIMENSION IN INCHES						AREA IN SQ INCHES		
SIZE	MAT.	P	C	P+C	FV	P+C +FV	SS	P+C +SS	PWC	PWC +C	PWW	PWW +C	PL	PL +C	UH	LH	TOTAL AREA
SHORT	AL_2O_3	180	32	212	128	340	5	217	9.4	9.6	14.4	14.9	13.1	13.2	100.2	76.8	177.0
	B4C	156	32	188	128	316	5	193									
REG.	AL_2O_3	192	34	226	128	354	6	232	9.5	9.7	14.4	14.9	13.9	14.1	103.2	87.0	190.2
	B4C	160	34	194	128	322	6	200									
LARGE	AL_2O_3	242	39	281	128	409	7	288	10.9	11.1	16.4	17.1	14.8	15.0	122.8	108.8	231.6
	B4C	192	39	231	128	339	7	238									

KEY:

P = Plate
C = Carrier
FV = Fragment Vest M1952

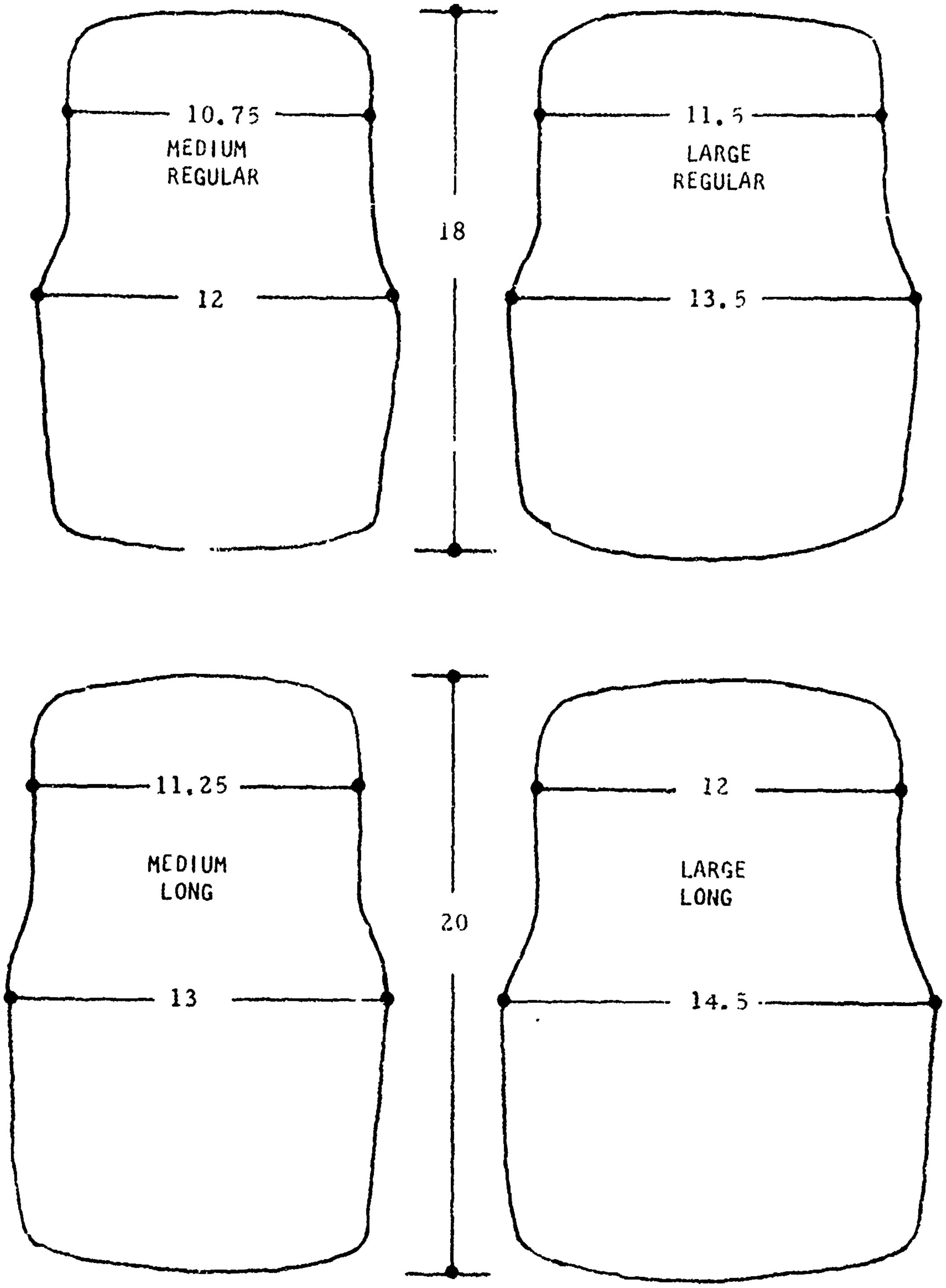
SS = Spall Shield Felt
PWC = Plate Width Chest
PWW = Plate Width Waist

PL = Plate Length Center Line
UH = Upper Half
LH = Lower Half



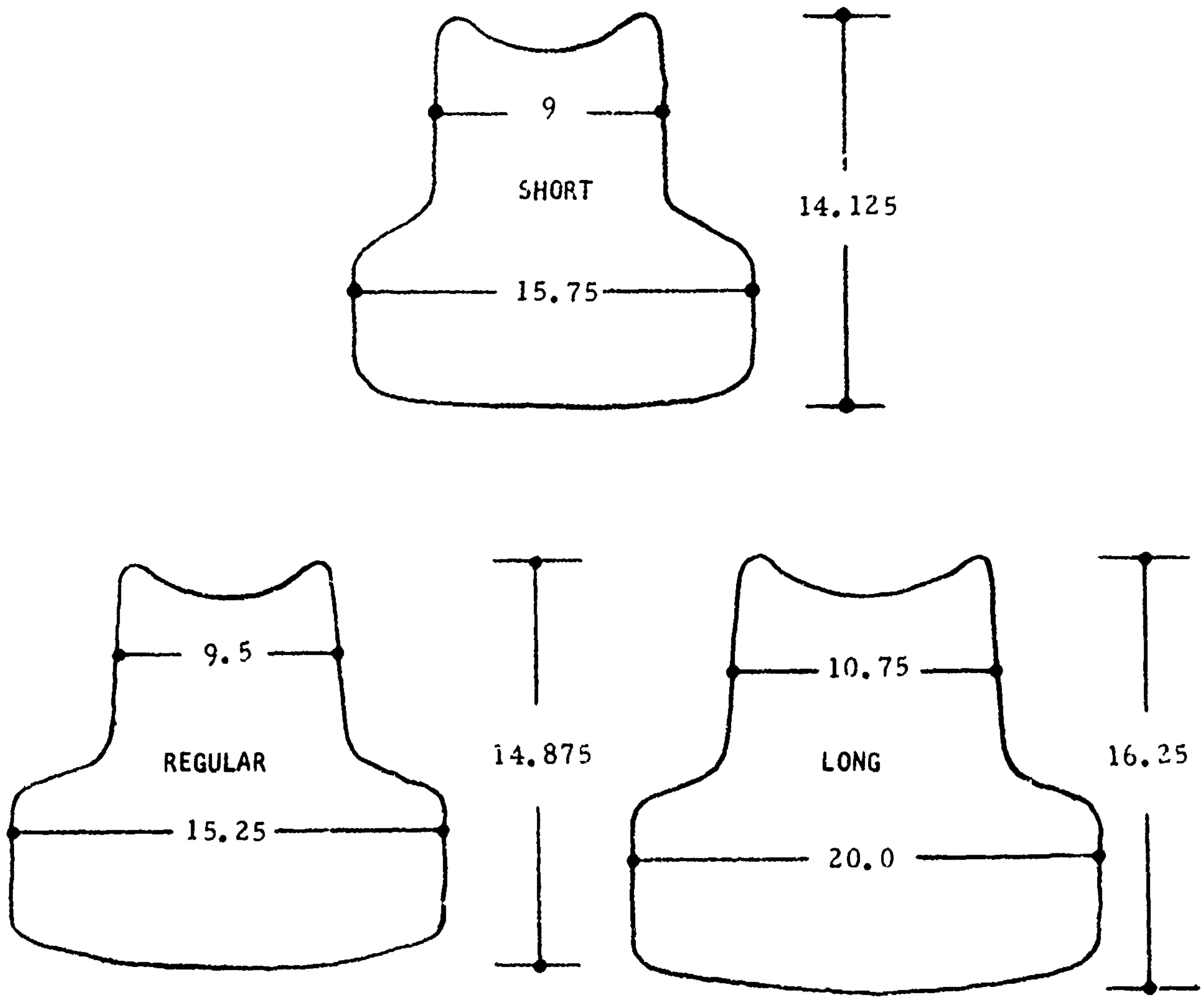
ACBA FRONT PLATE DIMENSIONS IN INCHES

FIGURE 2



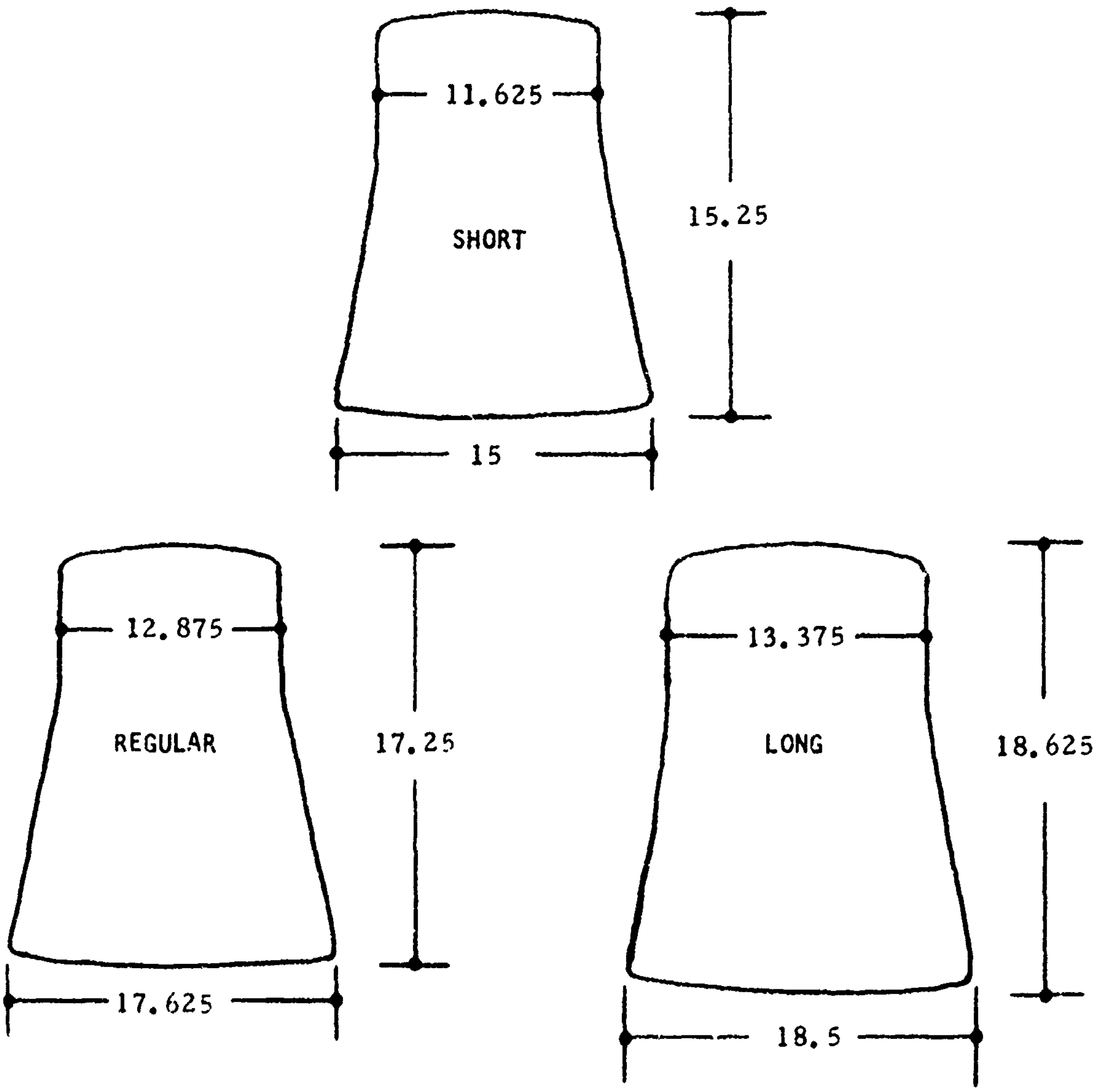
ACBA BACK PLATE DIMENSIONS IN INCHES

FIGURE 3



SBA FRONT PLATE DIMENSIONS IN INCHES

FIGURE 4



SBA BACK PLATE DIMENSIONS IN INCHES

FIGURE 5

Fig. 6

Front and Side View ACBA and SBA Systems Seat Position

METHOD

Subjects

This subject sample does not differ significantly from the subject population contained in US Army Natick Laboratories' TR-EP-150, "Anthropometry of Army Aviators."

Table 4 presents the summary statistics for the subject population.

Procedure

Anthropometric measures were taken in accordance with Hertzburg and Daniels, WADC TR 52-321, "Anthropometry of Flying Personnel - 1950." All measures were taken using a Modified US Navy BUWEPS 64A105H1-1 Integrated Anthropometric Measuring Device and a set of Standard Siber Hegner Anthropometric Measuring Instruments.

Twenty-five measures were taken with subjects in shorts, 13 with subjects in fatigues or flight suit, and 9 with subjects wearing fitted armor plates with carriers. All measures except weight and height were taken in the seated position. (See Appendix C for Sample Data Form.) Basic measures were: weight, height, sitting eye-shoulder height, neck-shoulder-chest-waist-hip breadths, arm reach, chest-stomach depth, neck-chest-stomach circumferences, buttock-knee-leg length, waist front, thigh top-sternal notch-scye sternal notch to mandible, and head length (Figs. 7 through 14).

Using a counterbalanced presentation, each subject was then fitted with either an ACBA or SBA plate/carrier in accordance with the appropriate fitting chart. All plate tops were aligned with the sternal notch of the subject and the carrier adjusted accordingly.

After fitting and anthropometric measurements, each subject performed a series of standard movements in the standing and seated positions as follows:

Torso: Bend forward, bend backward, bend to each side, rotate to each side.

Arms: Reach forward, reach across, reach overhead, reach to sides, reach to rear.

Throughtout this exercise routine, the subject reported the location and severity of any binding or pressure. Then each subject was remeasured for selected dimensions to determine changes or shifts in vest position relative to certain anatomical landmarks. Where fitting criteria indicated two possible sizes, the subject was measured in each size. This same procedure was then repeated using the SBA or ACBA as specified in the experimental design. Finally, the entire exercise sequence was repeated twice, with the subject wearing (alternately) the B_4C (boron carbide) counterpart of his "best fit" size for SBA and ACBA vests. Since the B_4C vest dimensions were identical with their $A1_2O_3$ counterparts, and identical carriers were used, the only anthropometric measure which could vary (due to weight) was vertical sag. Changes in this measure are reported in Task I, Section B, Tables 13 and 14.

TABLE 4

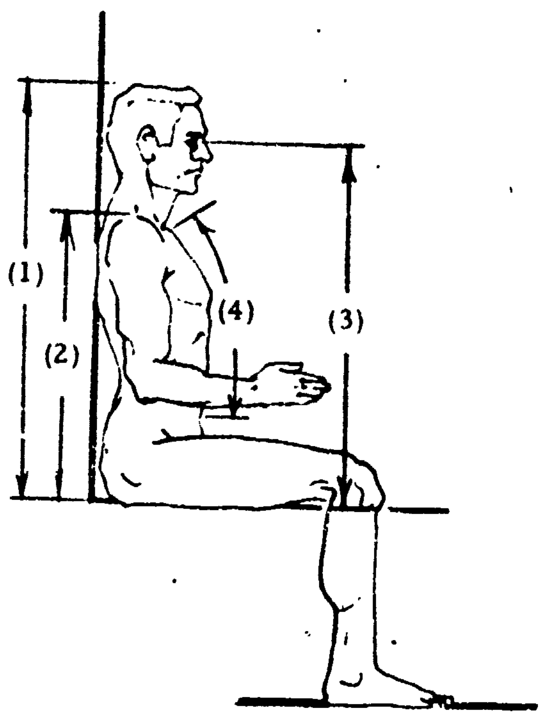
SUMMARY SUBJECT AGE, WEIGHT AND STATURE

ENLISTED SUBJECTS N = 30

MEASURE	RANGE	MEAN	STD. DEVIATION
AGE (Yrs.)	19-25	22.4	1.8
WEIGHT (Lbs)	118-213	163.9	23.3
STATURE (Inches)	63.5-74.0	69.6	2.5

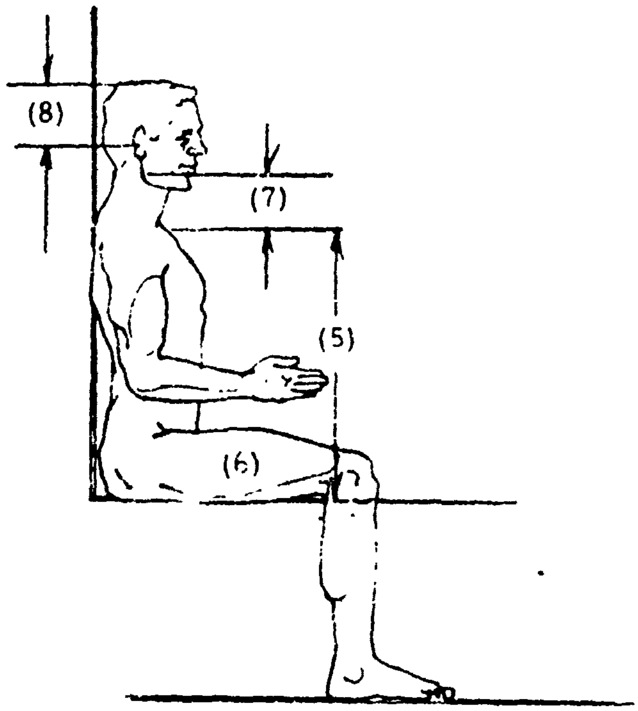
PILOT SUBJECTS N = 6

MEASURE	RANGE	MEAN
AGE (Yrs.)	23-33	28.0
WEIGHT (Lbs)	127-208	175.8
STATURE (Inches)	66.4-74.5	70.0



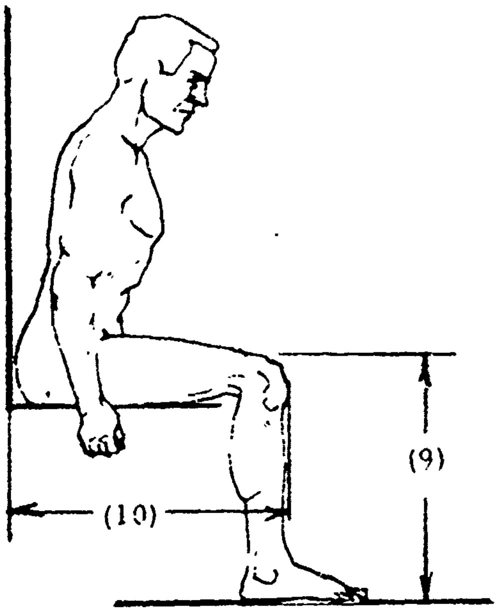
1. SEATED HEIGHT
2. SHOULDER HEIGHT
3. EYE HEIGHT
4. WAIST FRONT LENGTH

Fig. 7



5. STERNAL NOTCH TO SEAT SURFACE (TRUNK HEIGHT)
6. THIGH CLEARANCE HEIGHT
7. STERNAL NOTCH TO GONION
8. MENTON TO VERTEX (HEAD HEIGHT)

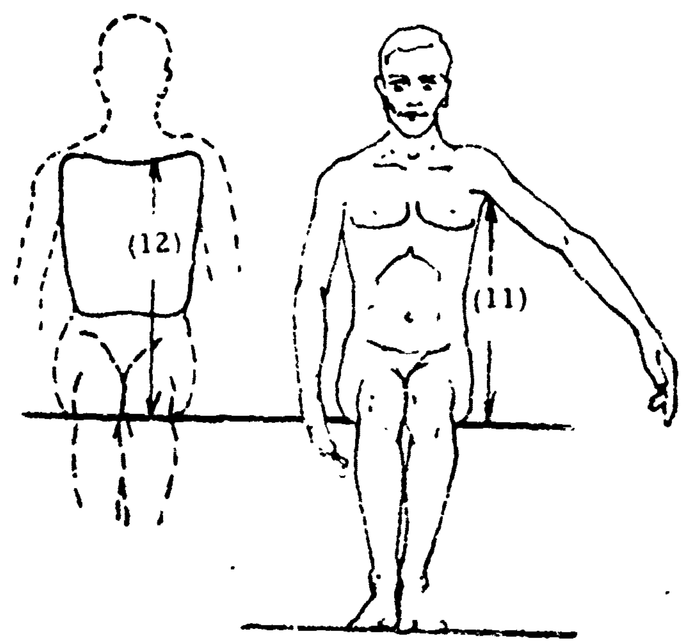
Fig. 8



9. LEG LENGTH

10. BUTTOCK-KNEE LENGTH

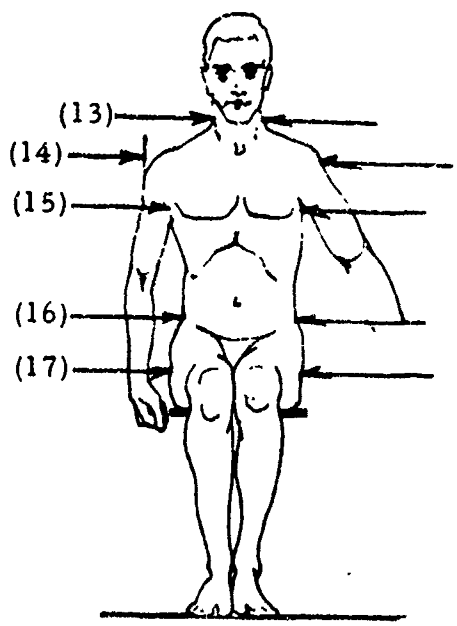
Fig. 9



11. SCYE TO SEAT SURFACE

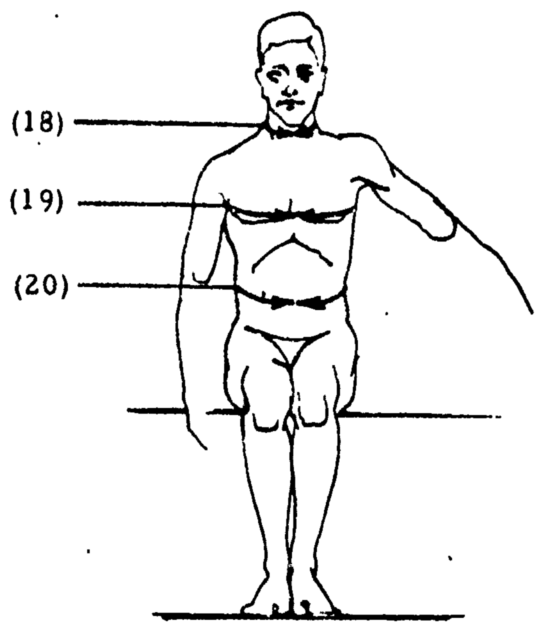
12. ARMOR PLATE TO SEAT SURFACE

Fig. 10



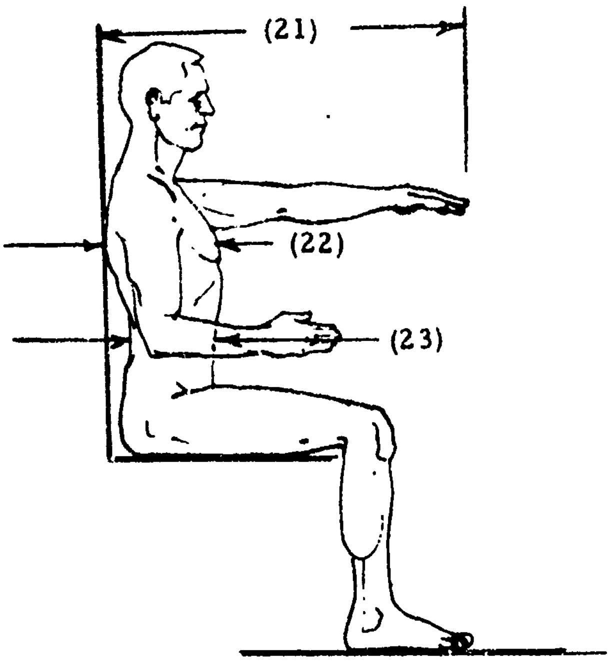
13. NECK BREADTH
14. SHOULDER BREADTH
15. CHEST BREADTH
16. WAIST BREADTH
17. HIP BREADTH

Fig. 11



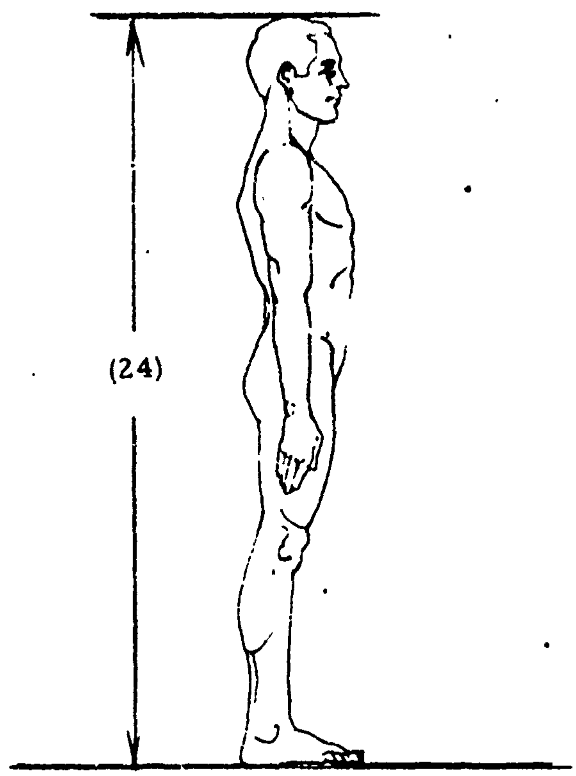
18. NECK CIRCUMFERENCE
19. CHEST CIRCUMFERENCE
20. WAIST CIRCUMFERENCE

Fig. 12



21. ARM-REACH
22. CHEST DEPTH
23. STOMACH DEPTH

Fig. 13



24. STATURE

25. WEIGHT

Fig. 14

RESULTS

Fitting

The first suitability measure is an assessment of the ACBA and SBA sizing systems. The criteria provided by US Army Natick Laboratories for fitting each system are shown in Tables 1 and 2.

Table 5 summarizes the fitting parameters for the ACBA and Table 6 summarizes these parameters for the SBA. These parameters can be compared against the subject's choice of armor size based upon a subjective feel for fit after doing the exercise outlined in the Procedure Section. Generally, the sizing criteria for both systems are marginally successful. Note that in Table 5 or 6, 50 percent of the subjects chose the SBA over the Proposed ACBA System.

Tables 7 and 8 are summaries of subject comments based upon the exercise routine for the ACBA (Table 7) and SBA (Table 8). Note that in both Tables 7 and 8 some form of binding or pressure was reported.

Anthropometry - Selected Measures

The following section contains comparisons between measures taken on subjects in fatigues (or flight clothing) and those same subjects in a fitted armor plate. Although a number of such comparisons are possible, those presented here are potentially important in determining an operators safety and/or mobility within the crew station.

a. Chest and Stomach Depths - The measurements shown in Tables 9, 10 and 11 represent mobility determinants within the crew station, i.e., seat width, seat depth, shoulder armor depth, and seat side armor depth.

b. Waist Breadth - This measurement is the most important of Figures 4, 5 and 6. This is the basic seat width determinant as well as an indicator of coverage in the lower torso area.

c. Armor Plate Sag - These measurements have safety implications, i.e., horizontal plate sag determines upper wing proximity of the plate to the thigh tops and upper groin area. These two measures correspond respectively to the plate top edge (wing to wing) and the plate bottom edge, the injury producing portions of the plate.

TABLE 5

FITTING - ACBA

ENLISTED MEN

S NO.	WAIST FRONT & CHEST BREADTH	WAIST FRONT & CHEST CIRCUM.	CHART FIT	* BEST FIT	OTHER SIZES TRIED	SUBJECT PREFERENCE
1	ML/LL	ML	ML	MR	ML,LR	ANATOMIC
2	NO FIT	NO FIT	NO FIT	MR	--	STANDARD
3	LR/ML	MR	LR,MR,ML	MR	ML	STANDARD
4	ML	ML	ML	LR	ML	STANDARD
5	ML	ML	ML	LR	ML	NO DIFF.
6	LL	LL	LL	LL	ML	STANDARD
7	LR/LL	MR	LR,MR	LR	--	ANATOMIC
8	LR	MR	LR,MR	LR	MR	ANATOMIC
9	ML	NO FIT	ML	ML	LL	STANDARD
10	LL	LL	LL	ML	LL	STANDARD
11	LR	MR	LR,MR	MR	LR	ANATOMIC
12	LR	MR	LR,MR	LR	--	ANATOMIC
13	MR	MR	MR	MR	--	ANATOMIC
14	LR	MR	LR,ML	LR	--	ANATOMIC
15	ML	LL	ML,LL	LR	ML	ANATOMIC
16	MR	MR	MR	MR	--	STANDARD
17	MR	MR	MR	MR	--	ANATOMIC
18	ML	ML	ML	LR	ML	ANATOMIC
19	ML	ML	ML	LR	ML	ANATOMIC
20	LR	MR	LR,MR	LR	MR	STANDARD
21	LR	MR	LR,MR	LR	MR	STANDARD
22	LL	ML	LL,ML	LL	ML	STANDARD
23	MR/LL	MR	MR,LL	MR	LL	ANATOMIC
24	LR	LR	LR	LR	MR	STANDARD
25	MR	NO FIT	MR	MR	--	ANATOMIC
26	MR	MR	MR	MR	--	STANDARD
27	ML	NO FIT	ML	LR	ML	NO DIFF.
28	LR	MR	LR,MR	LR	MR	ANATOMIC
29	LR/LL	LR/ML	LR,ML,LL	LR	MR	ANATOMIC
30	MR	MR	MR	LR	MR	STANDARD

PILOTS

S NO.	WAIST FRONT & CHEST BREADTH	WAIST FRONT & CHEST CIRCUM.	CHART FIT	* BEST FIT	OTHER SIZES TRIED	SUBJECT PREFERENCE
P1	LR/ML	LR/ML	LR,ML	LR	--	STANDARD
P2	LR	MR	LR,MR	ML	LR,MR	STANDARD
P3	NO FIT	NO FIT	NO FIT	LR	--	ANATOMIC
P4	LR	LR	LR	LR	MR	STANDARD
P5	LL	ML	LL,ML	LL	ML	STANDARD
P6	NO FIT	LR	LR	LR	--	ANATOMIC

* Subject and experimenter agree after subject has performed prescribed set of body movements.

KEY: MR = Medium Regular LR = Large Regular ML = Medium Long LL = Large Long

TABLE 6

FITTING - SBA

ENLISTED SUBJECTS

SN	HEIGHT	SHOULDER HEIGHT	SHOULDER BREADTH	CHEST DEPTH	CHART FIT	* BEST FIT	OTHER SIZES TRIED	SUBJECT PREFERENCE
	Fitting Parameters							
1	R	L	R	R	R	R	L	Anatomic
2	R	L	S	R	R	R	-	Standard
3	L	L	R	R	LR/R	L	R	Standard
4	S	L	R	L	R	R	-	Standard
5	R	L	L	R	R	R	-	No Difference
6	L	L	L	R	L	L	-	Standard
7	L	L	R	S	L/R	R	L	Anatomic
8	L	L	R	S	L/R	R	L	Anatomic
9	L	L	L	S	L	L	R	Standard
10	R	L	L	R	L/R	R	L	Standard
11	R	R	R	R	R	R	-	Anatomic
12	L	L	R	S	L/R	R	L	Anatomic
13	R	R	R	S	R	R	-	Anatomic
14	L	L	R	R	L/R	R	L	Anatomic
15	L	L	L	R	L	L	-	Anatomic
16	R	R	R	S	R	R	-	Standard
17	S	R	S	S	S	S	-	Anatomic
18	R	R	R	R	R	R	-	Anatomic
19	R	L	S	S	R/S	R	S	Anatomic
20	S	S	R	S	S	S	-	Standard
21	S	R	S	S	S	S	-	Standard
22	L	L	L	S	L	L	-	Standard
23	R	R	R	R	R	R	-	Anatomic
24	R	R	R	R	R	R	-	Standard
25	S	S	S	S	S	S	-	Anatomic
26	R	R	S	S	R/S	S	R	Standard
27	L	R	S	S	L/R	R	L	No Difference
28	S	R	R	S	R/S	R	S	Anatomic
29	R	R	R	R	R	R	L	Anatomic
30	R	R	R	S	R	R	-	Standard

PILOTS

SN	HEIGHT	SHOULDER HEIGHT	SHOULDER BREADTH	CHEST DEPTH	CHART FIT	* BEST FIT	OTHER SIZES TRIED	SUBJECT PREFERENCE
	Fitting Parameters							
1	R	R	S	R	R	R	-	Standard
2	R	R	R	S	R	R	-	Standard
3	L	R	R	L	L/R	R	L	Anatomic
4	S	R	S	S	R/S	R	S	Standard
5	L	L	L	R	L	L	-	Standard
6	R	R	L	R	R		-	Anatomic

* Subject and Experimenter agree after subject has performed prescribed set of body movements

KEY: S = Short R = Regular L = Large

TABLE .. ACBA Subjective Evaluation during Exercise Routine

DIR OF MOV	TORSO BENDING					
	STANDING	ENLISTED SUBJS. N = 30	PILOT SUBJS N = 6	SEATED	ENLISTED SUBJS. N = 30	PILOT SUBJS N = 6
FORWARD TO 45°	groin binding can't bend to 45° stomach pressure chin hits armor wings chin hits plate top	3 1 1 20 3	2 0 0 5 0	groin binding can't bend to 45° thigh fold binding chin hits plate top chin hits armor wings throat pressure iliac crest binding	3 1 1 4 16 3 1	3 0 2 0 6 0 0
REARWARD						
SIDES (LEFT & RIGHT)	thigh fold binding rib cage binding chin hits armor wings rides on hips iliac crest pressure	1 6 1 1 0	2 1 0 0 1	thigh fold binding rib cage binding iliac crest pressure chin hits armor wings	7 3 6 2	6 0 0 0
ROTATION (LEFT & RIGHT)	drag across thighs rib cage binding iliac crest binding	1 2 1		can't rotate plate drag across groin area thigh fold binding iliac crest binding deltoid binding	1 1 4 2 0	1 0 2 0 1

DIR OF MOV	ARM REACHING					
	STANDING	ENLISTED SUBJS. N = 30	PILOT SUBJS. N = 6	SEATED	ENLISTED SUBJS. N = 30	PILOT SUBJS. N = 6
FORWARD & ACROSS (LEFT & RIGHT)	pectorial binding neck pressure deltoid binding	1 1 10	0 0 3	pectorial binding deltoid binding biceps binding	2 11 1	0 2 0
OVERHEAD	neck pressure shoulder binding rib cage binding	5 5 1	4 0 0	shoulder binding neck pressure rib cage binding	6 5 2	2 3 0
SIDES (LEFT & RIGHT)	sternum pressure	0	1	sternum pressure	0	1
BEHIND	binding at scye sternum pressure	1 0	0 1	binding at scye sternum pressure	1 0	1 1

TABLE 8. SBA Subjective Evaluation during Exercise Routine

	TORSO BENDING					
DIRECTION OF MOVEMENT	STANDING	ENLISTED SUBJS. N = 30	PILOT SUBJS. N = 6	SEATED	ENLISTED SUBJS. N = 30	PILOT SUBJS. N = 6
FORWARD TO 45°	.Groin Binding	2	1	.Chin Contacts Armor Wings	20	6
	.Chin Contacts Armor Wings	22	6	.Material Binding at the Throat (Front)	1	0
	.Chin Contacts Armor Top Between Wings	2	0	.Groin Binding	2	0
REARWARD	No Recorded Comments			No Recorded Comments		
SIDES (Left & Right)	.Chin Contacts Armor Wings	4	0	.Chin Contacts Armor Wings	3	0
				.Chin Contacts Armor Plate between Wings	1	0
				.Throat Contacts Armor Plate between Wings	1	0
				.Thigh-Top Binding	3	0
				.Iliac Crest Pressure	3	1
ROTATION (Left & Right)	.Deltoid Binding	1	1	.Rides on Thighs	1	0
				.Thigh Binding	1	0
				.Pressure on Sides of Neck	1	0
				.Deltoid Binding	1	1

TABLE 8. (Continued) SBA Subjective Evaluation during Exercise Routine

DIRECTION OF MOVEMENT	ARM REACHING					
	STANDING	ENLISTED SUBJS. N = 30	PILOT SUBJS. N = 6	SEATED	ENLISTED SUBJS. N = 30	PILOT SUBJS. N = 6
FORWARD & ACROSS (Left & Right)	.Deltoid Binding	15	5	.Bicep Binding	1	0
	.Neck Pressure on Sides	2	0	.Deltoid Binding	13	5
				.Neck Pressure on Sides	2	1
OVERHEAD	.Shoulder Binding	9	1	.Shoulder Binding	7	2
	.Neck Pressure	9	4	.Neck Pressure	10	4
	.Chin Contacts Armor Plate	.1	1	.Throat Contacts Plate	1	1
SIDES (Left & Right)	.Collar Bone Pressure	0	1	No Recorded Comments		
BEHIND	.Deltoid Binding	1	0	.Deltoid Binding	1	0
	.Collar Bone Pressure	0	1	.Collar Bone Pressure	0	1

TABLE 9

ACBA	ARMOR PLATE SIZE											
	MEDIUM REGULAR			LARGE REGULAR			MEDIUM LONG			LARGE LONG		
	FATIGUES	ARMOR	MEAN DIFF. INC.	FATIGUES	ARMOR	MEAN DIFF. INC.	FATIGUES	ARMOR	MEAN DIFF. INC.	FATIGUES	ARMOR	MEAN DIFF. INC.
MEAN CHEST DEPTH	8.6	10.6	2.0	8.8	10.9	2.1	9.2	11.4	2.2	9.2	11.2	2.0
MEAN STOMACH DEPTH	9.0	10.8	1.8	9.0	11.1	2.1	9.3	11.4	2.1	10.0	11.8	1.8

CHEST AND STOMACH DEPTHS IN INCHES

TABLE 10

SBA	ARMOR PLATE SIZE								
	SHORT			REGULAR			LONG		
	FATIGUES	ARM.	MEAN DIFF. INC.	FATIGUES	ARM.	MEAN DIFF. INC.	FATIGUES	ARM.	MEAN DIFF. INC.
MEAN CHEST DEPTH	7.8	9.7	1.9	9.0	10.7	1.7	9.2	10.8	1.6
MEAN STOMACH DEPTH	7.8	10.0	2.2	9.2	11.1	1.9	9.8	11.3	1.5

CHEST AND STOMACH DEPTHS IN INCHES

TABLE 11

ACBA	ARMOR PLATE SIZE											
	MEDIUM REGULAR			LARGE REGULAR			MEDIUM LONG			LARGE LONG		
	FATIGUES	ARMOR	MEAN DIFF. INC.	FATIGUES	ARMOR	MEAN DIFF. INC.	FATIGUES	ARMOR	MEAN DIFF. INC.	FATIGUES	ARMOR	MEAN DIFF. INC.
MEAN CHEST CIRCUM.	35.8	39.8	4.0	37.2	42.0	4.8	39.7	43.6	4.1	39.4	44.[illegible]	5.2
MEAN STOMACH CIRCUM.	32.7	40.8	8.1	33.7	43.2	9.5	35.4	43.0	7.6	37.4	46.1	8.7

CHEST AND STOMACH CIRCUMFERENCES IN INCHES

SBA	ARMOR PLATE SIZE								
	SHORT			REGULAR			LONG		
	FATIGUES	ARM.	MEAN DIFF. INC.	FATIGUES	ARM.	MEAN DIFF. INC.	FATIGUES	ARM	MEAN DIFF. INC.
MEAN CHEST CIRCUM.	34.1	37.9	3.8	37.4	40.2	2.8	38.7	42.4	2.7
MEAN STOMACH CIRCUM.	29.9	38.4	8.5	34.2	41.3	7.1	35.9	43.6	7.7

CHEST AND STOMACH CIRCUMFERENCES IN INCHES

TABLE 11

ACBA	ARMOR PLATE SIZE											
	MEDIUM REGULAR			LARGE REGULAR			MEDIUM LONG			LARGE LONG		
	FATIGUES	ARMOR	MEAN DIFF. INC.	FATIGUES	ARMOR	MEAN DIFF. INC.	FATIGUES	ARMOR	MEAN DIFF. INC.	FATIGUES	ARMOR	MEAN DIFF. INC.
MEAN CHEST CIRCUM.	35.8	39.8	4.0	37.2	42.0	4.8	39.7	43.6	4.1	39.4	44.[illegible]	5.2
MEAN STOMACH CIRCUM.	32.7	40.8	8.1	33.7	43.2	9.5	35.4	43.0	7.6	37.4	46.1	8.7

CHEST AND STOMACH CIRCUMFERENCES IN INCHES

SBA	ARMOR PLATE SIZE								
	SHORT			REGULAR			LONG		
	FATIGUES	ARM.	MEAN DIFF. INC.	FATIGUES	ARM.	MEAN DIFF. INC.	FATIGUES	ARM	MEAN DIFF. INC.
MEAN CHEST CIRCUM.	34.1	37.9	3.8	37.4	40.2	2.8	38.7	42.4	2.7
MEAN STOMACH CIRCUM.	29.9	38.4	8.5	34.2	41.3	7.1	35.9	43.6	7.7

CHEST AND STOMACH CIRCUMFERENCES IN INCHES

TORSO BINDING

TORSO BINDING

TORSO BINDING

TORSO BINDING

FIGURE 15

HORIZONTAL & VERTICAL SAG COMBINATION

HORIZONTAL SAG

PLATE AT FITTED HEIGHT

PLATE WITH VERTICAL SAG

FIGURE 16

FIGURE 17

CHIN-THROAT CONTACT

SUMMARY

Items a through c when considered together form the basis of recommendations for both carrier and plate. In a majority of cases the data was validated by the comments of the subjects. For example, horizontal sag tended to equate with reports of chin, throat, or jaw encountering the armor plate top or wings when the neck was moderately extended forward. Vertical sag corresponded to reports of groin pressure and binding across the thighs. The principal conditions underlying both types of sag appear related to excessive length or plates and lack of sufficient adjustment capability in the carrier.

Area Coverage

This data is presented in its entirety to give a notion of the range of exposures across subjects, by system type (ACBA or SBA) and within plate sizes (Tables 13 through 18).

For purposes of this analysis subject torso area was estimated using the following procedure:

a. Upper/lower torso height (frontal area) - Sternal notch to seat surface item (5) Figure 8, minus thigh clearance height item (6), Figure 8 derives lines AB and A'B' Figure 18.

b. Upper/lower torso breadth (frontal area) - Chest breadth item (15) Figure 11 derives line BB' Figure 18.

c. Upper/lower torso depth (side area) - Chest depth item (22) Figure 13 derives line CA Figure 18. Stomach depth item (23) Figure 13 derives line DB Figure 18.

TABLE 13

ACBA VERTICAL AND HORIZONTAL SAG

		MR	LR	ML	LL
MEAN VERTICAL SAG	Al_2O_3	1.8	2.1	1.2	1.8
	B_4C	.9	.9	.9	1.0
MEAN HORIZONTAL SAG	Al_2O_3 Only	2.4	1.9	4.5	3.5

TABLE 14

SBA VERTICAL AND HORIZONTAL SAG

		S	R	L
MEAN VERTICAL SAG	Al_2O_3	.2	.7	1.1
	B_4C	.3	.2	.8
MEAN HORIZONTAL SAG	Al_2O_3 Only	2.2	2.0	2.3

TABLE 15. ACBA Approximate Area Coverage - Frontal

SIZE MEDIUM REGULAR				
NUMBER IN SQUARE INCHES			DIFFERENCE	
SUBJECT NO.	SUBJECT TORSO AREA	ARMOR PLATE AREA	COVERED	EXPOSED
1	213.0	205.7		7.3
2	190.5	205.7	15.2	
3	194.0	205.7	11.7	
11	185.2	205.7	20.5	
13	173.6	205.7	32.1	
16	187.6	205.7	18.1	
17	178.4	205.7	27.3	
23	187.6	205.7	18.1	
25	165.8	205.7	39.9	
26	178.1	205.7	27.6	
SIZE MEDIUM LONG				
9	194.1	254.8	60.7	
10	230.2	254.8	24.6	
SIZE LARGE REGULAR				
4	213.4	216.0	2.6	
5	220.2	216.0		4.2
7	218.1	216.0		2.1
8	204.8	216.0	11.2	
12	194.9	216.0	21.1	
14	219.5	216.0		3.5
15	224.8	216.0		8.8
18	207.3	216.0	8.7	
19	201.2	216.0	14.8	
20	172.9	216.0	43.1	
21	187.8	216.0	28.2	
24	222.6	216.0		6.6
27	195.8	216.0	20.2	
28	189.6	216.0	26.4	
29	202.0	216.0	14.0	
30	192.9	216.0	23.1	
SIZE LARGE LONG				
6	236.6	272.5	36.0	
22	226.6	272.5	46.0	

TABLE 16

ACBA APPROXIMATE AREA COVERAGE - SIDE

SIZE MEDIUM REGULAR

NUMBER GIVEN IN SQUARE INCHES	ARMOR PLATE AREA	MEAN EXPOSED AREA
SIDE COVERAGE AVG.	34.0	112.3

SIZE MEDIUM LONG

NUMBER GIVEN IN SQUARE INCHES	ARMOR PLATE AREA	MEAN EXPOSED AREA
SIDE COVERAGE AVG.	51.0	103.5

SIZE LARGE REGULAR

NUMBER GIVEN IN SQUARE INCHES	ARMOR PLATE AREA	MEAN EXPOSED AREA
SIDE COVERAGE AVG.	40.0	112.1

SIZE LARGE LONG

NUMBER GIVEN IN SQUARE INCHES	ARMOR PLATE AREA	MEAN EXPOSED AREA
SIDE COVERAGE AVG.	52.0	112.8

TABLE 17. SBA Approximate Area Coverage - Frontal

SIZE MEDIUM REGULAR				
NUMBER IN SQUARE INCHES			DIFFERENCE	
SUBJECT NO.	SUBJECT TORSO AREA	ARMOR PLATE AREA	COVERED	EXPOSED
17	178.4	177.0		1.4
20	172.9	177.0	4.1	
21	187.8	177.0		10.8
25	165.8	177.0	11.2	
26	178.1	177.0		1.1
SIZE REGULAR				
1	213.0	190.2		22.8
2	190.5	190.2		.3
4	213.4	190.2		23.2
5	220.2	190.2		30.0
7	218.1	190.2		27.9
8	204.8	190.2		14.6
10	230.2	190.2		40.0
11	185.2	190.2	5.0	
12	194.9	190.2		4.7
13	173.6	190.2	16.6	
14	219.5	190.2		29.3
16	187.6	190.2	2.6	
18	207.3	190.2		17.1
19	201.2	190.2		1.1
23	187.6	190.2		2.6
24	222.6	190.2		32.4
27	195.8	190.2		5.6
28	189.6	190.2	.6	
29	202.0	190.2		11.8
30	192.9	190.2		2.7
SIZE LARGE				
3	194.0	231.6	37.6	
6	236.6	231.6		5.0
9	191.4	231.6	40.2	
15	224.8	231.6	6.8	
22	226.6	231.6	5.0	

TABLE 18

SBA APPROXIMATE AREA COVERAGE - SIDE

SIZE SHORT

NUMBER GIVEN IN SQUARE INCHES	ARMOR PLATE AREA	EXPOSED
SIDE COVERAGE AVG.	18.0	110.9

SIZE REGULAR

NUMBER GIVEN IN SQUARE INCHES	ARMOR PLATE AREA	EXPOSED
SIDE COVERAGE AVG.	18.0	125.8

SIZE LARGE

NUMBER GIVEN IN SQUARE INCHES	ARMOR PLATE AREA	EXPOSED
SIDE COVERAGE AVG.	23.0	144.9

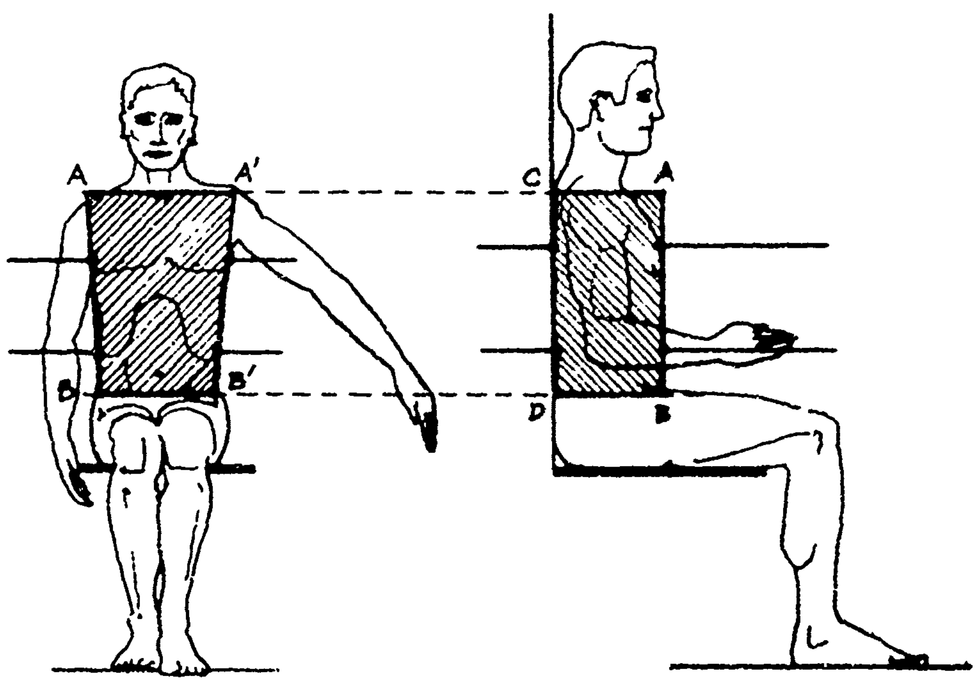


Fig. 18

TASK V - EFFECTS ON OPERATOR PERFORMANCE

INTRODUCTION

As originally proposed, the HFE assessment of the effects of SBA and ACBA on operator performance included both laboratory and field type evaluations. The laboratory task (multi-limb coordination and target detection) was not performed due to nonavailability of modified ACBA plates and carriers. The field observations however, were made as scheduled, and the results appear in the following section, "Cockpit Assessments."

For the purposes of clarity the term vest will constitute the combination of plate and carrier. Throughout this assessment the SBA system was used for comparison with the ACBA system. Each subject performed identical activities using both the ACBA and SBA systems in both weight classes provided (Fig. 19).

In addition, mid-point in the program an "improved" carrier system was introduced by NLABS and this system was subjected to a cursory assessment. The improved carrier was fabricated of ballistic nylon and provided fragment protection around the periphery of the hard plate. It also provided a single-point quick release feature for the shoulder closures and the back position of pilot/copilot ensembles was fabricated of solid material and did not contain a plate pocket. This system will be referred to as the ISBA (Fig. 20). An evaluation of the ISBA system was conducted using members of a National Guard unit as subjects. Results are reported elsewhere; mention is made here of the evaluation simply to indicate that time and effort were expended at the expense of the ongoing ACBA project.

It should be noted that the SBA was evaluated for body restriction (Ref. 1) prior to this program. Therefore, the discussion for the most part will be confined to the ACBA.

COCKPIT ASSESSMENTS

METHOD

1. Subjects - Six Army Aviators

2. Apparatus - Aviator Clothing/Equipment ensembles

ASSESSMENT ITEMS

a. ACBA System (Al_2O_3)

b SBA (Al_2O_3)

c. ACBA System (BAC)

d. SBA System (BAC)

BASIC ITEMS

a. Flying Helmet SPH-4

b. Nomex Flying Clothing (2 pcs)

c. Underwear and Socks

d. Combat Boots

e. Nomex/Leather Flying Gloves

f. Weapon, Cal. 45 auto w/mag.

g. Pistol Belt, Web-Type w/Leather Holster

AUXILIARY ITEMS

a. SRU-21 Survival Vest w/Components

b. OV-1 Survival Vest w/Components

c. OV-1 Martin-Baker Seat Harness

AIRCRAFT

a. OH-6

b. OH-58

c. AH-1G

d. UH-1D

e. OV-1B

PROCEDURE

Each subject systematically performed the following sequence:

1. Donning/doffing each ensemble.
2. Ingress/egress each aircraft in a normal manner, then as rapidly as possible.
3. Adjust seat.
4. Position seat armor (where applicable).
5. Adjust anti-torque pedals.

TYPICAL COCKPIT ASSESSMENT ENSEMBLE LESS FLIGHT HELMET

ACBA SYSTEM

Fig. 19

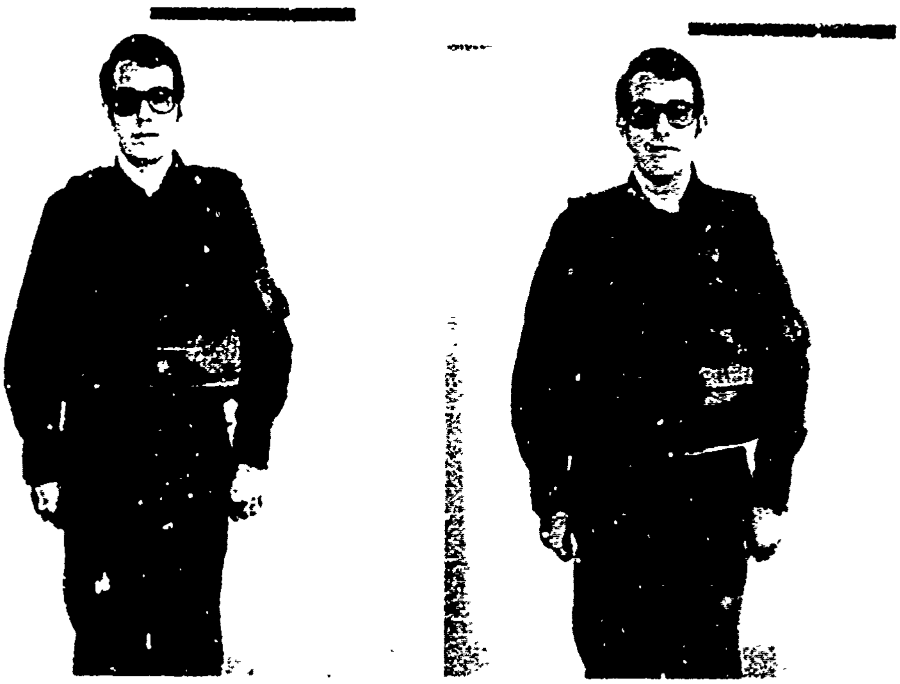


Fig. 20

ISBA ISBA w/SRU 21

6. Couple restraint system.

7. Adjust selected flight instruments.

8. Exercise cyclic control envelope.

9. Exercise collective control envelope.

10. Exercise control stick (OV-1B).

11. Exercise power/prop controls (OV-1B).

12. Adjust fire control sight (fixed).

13. Exercise fire control sight (moveable).

RESULTS

The predominant operational body attitude assumed by a pilot or copilot is the seated position. All other body attitudes are transitory and occur only when entering and exiting the aircraft. Classically, the aviator's seated position is characterized by a slight forward and downward slump of the head and upper torso. For reasons of comfort and to facilitate aircraft control the right fore- (cyclic control), is rested diagonally across the top of the right thigh.

From the on-set of this assessment it became apparent that the ACBA system design was geometrically optimized and sized for a standing position. As a result of the standing design premise, undesirable vest characteristics can be readily isolated and discussed in terms of three dimensions. The critical dimensions are:

a. Plate length on center (PLC).

b. Plate length at each shoulder (PLS).

c. Plate width at chest cavity (PWC).

These three dimensions directly determine the extent to which a given vest will interact with normal body movements. The type of interaction can be described anatomically as follows:

a. PLC

1. forward torso flexion

2. neck flexion

3. lateral torso inclination

4. torso rotation

b. PLS

1. forward torso flexion
2. neck lateral motion
3. neck rotation
4. shoulder flexion

c. PWC

1. deltoid flexion
2. shoulder flexion
3. arm reach

Vest system thickness in combination with flight clothing (climatic environment dependent) and the survival vest produces a second series of dimensional interactions which have impact on the crew station geometry. For example, when any of the systems are used with the SRU-21 survival vest, thickness interacts singly and in combination with PLC, PLS and PWC to produce movement restrictions. The increases in body size associated with each system are shown in Table 19.

TABLE 19

ENSEMBLE ADDITION TO BODY MEASUREMENTS

	SBA	ACBA
BODY MEASURE	SRU-21 w/STD	SRU-21 w/ANT
1. MEAN CHEST DEPTH	3.0	2.6
2. MEAN STOMACH DEPTH	5.7	5.7
3. MEAN CHEST CIRCUM.	9.2	6.5
4. MEAN STOMACH CIRCUM.	18.0	9.6
5. MEAN WAIST BREADTH	5.6	4.3

As indicated in Task I, Section B, the measurements represent mobility determinants within the aircrew station. Additionally, they provide design criteria for the crew station geometry, e.g., seat width, seat depth, shoulder armor depth and height, and seat side armor depth and height. In practical terms they limit the following seated functions or movements:

a. over-the-side vision

b. rearward vision

c. forward and rearward functional arm reach

d. torso rotation

e. forward and lateral torso bending

Their impact outside of the crew station is associated with ingress or egress (normal and emergency) and donning/doffing.

The ACBA system used singly or in combination with the SRU-21 survival vest was not considered satisfactory. For clarity in the discussion the analysis is broadly divided into three areas:

a. Body restriction (seated)

b. Body restriction (transition from seated to standing)

c. Safety

Except where specifically mentioned the interactions described are generic for all aircraft used in the analysis.

Body Restriction (seated)

Forward and cross body arm reach were severely restricted. This was caused by plate width in the pectoral girdle area. These movements are associated with display adjustment, communication system channel selection, fire control system adjustment (or in the case of the copilot-gunner AH1G fire control system operation) cyclic stick control movement envelope and cross arm cyclic control.

Cyclic stick control movement rearward on center and rear-right position are restricted. This type of restriction is present in all aircraft except the AH-1G. Although each specific control stick position could be attained, in all cases, an abnormal body position was required. For rearward movements the right hand had to be rotated around the front of the grip. For rearward right movements the right hand had to be rotated around the front of the grip and the right leg either rotated right or lifted off the right anti-torque pedal.

Torso rotation left and right was restricted by binding of the anatomically fitted lower plate wings, at the thigh-trunk junction. This causes a serious reduction in visibility, physical discomfort, and awkward strained movements.

Torso bending forward was seriously restricted. This was caused by plate length and caused a reduction in forward arm reach, an awkward seated position, thus causing fatigue and poor body control relationship.

For the copilot-gunner in the AH-1G using the flexible sighting system, plate length and width caused a reduction in the engagement envelope, awkward sight movement and in the case of the large individual using the Large Long system, the inability to rotate the torso.

Body Restriction (transition from seated to standing)

Torso forward and lateral bending restriction was such that normal ingress/egress was complicated. The mobility to bend and rotate the upper torso in combination with system sagging defy adequate verbalization for the contortions the aviator must perform in order to enter or exit the various crew stations. Of particular note was the results of attempting an exit from the copilots station of the AH-1G. The canopy opening of this crew station requires an extreme forward and lateral bending movement to effect entry or exit. With the 95th percentile aviator wearing a Large Long ACBA plus the SRU-21 the sequence of movement required for entry was nearly impossible; to exit literally required falling out. Needless to say, that in a real emergency when the aircraft may not be in a normal attitude emergency egress cannot be accomplished.

Donning/doffing of the ACBA system is no more difficult or time consuming than with the current SBA system. Both systems require two separate and distinct sets of movements to be accomplished before separation. Neither system can be jettisoned in an emergency.

As indicated in Task I the adjustment system provided on the ACBA was inadequate thereby resulting in considerable system sag complicated by a tendency to shift with body movements.

Safety

ACBA plate length (irrespective of size) causes contact with the throat and jaw area of the aviator during any normal seat torso motion. This was particularly apparent when the aviator assumed a comfortable control/body relationship. Therefore, during turbulence, hard landing or a crash the probability is very high that the aviator will contact the plate upper edge.

ACBA plate upper edge cut also interacted with the restraint system in each aircraft. The upper edge is so configured that three distinct problems occur. The first is that the shoulder harness cannot be worn flat over the top mid-portion of the shoulder. It must be positioned to either side of the peripheral shoulder wings. If worn on the outboard side toward the deltoids, the system will continually slip off unless it is tighened to the point of discomfort. Second, if worn on the inboard side toward the neck, the straps produce irritation and discomfort by binding each side of the neck. Thirdly, the lap belt must be carefully routed under the lower edge of the plate to insure contact with the pelvic area. If worn over the ensemble the system is loose and will allow the aviator to submarine during a crash.

The ACBA system cannot be rapidly jettisoned. As described in 2b above, two complete sets of movements must be accomplished before the armor portion can be separated from the body. This causes a complete separation of survival vest from the control of the aviator.

CONCLUSIONS AND RECOMMENDATIONS

GENERAL

The Dimensional Suitability Task as defined is the key to an operationally acceptable aircrew armor system. The Human Factors Engineering Assessment must be sequential. Until a proposed system is suitably dimensioned and sized, for the aircrewman's needs, the conduct of other analyses does not result in meaningful information. The only meaningful approach requires that the proposed system be developed based on successive iterations, i.e., feedback loops in the Task I effort. The loop would make use of data gathered during Task I to modify a proposed system and recycle through Task I until it is suitable. This flexibility was not available during this assessment. Despite this inflexibility HEL provided a modified ACBA system (plates only) based on Task I data. Unfortunately proposed carrier modifications were never initiated by NLABS therefore, no additional assessments were conducted. However, even with the problems noted the ACBA system, with minor modifications, constitutes an improvement over the SBA system by:

a. Providing improved sizing capability.

b. Providing improved cockpit mobility and aviator dexterity.

c. Reducing the probability of throat and facial injuries in the event of hard landing or crash.

d. Providing improved body area coverage.

e. Being improved with the SRU-21 survival vest.

CONCLUSIONS FOR THE ACBA SYSTEM

Fabric Carrier: The carrier provided with the ACBA system contributed significantly to the poor overall system acceptability. Whether the problems detected were the result of poor design (the carrier provided the ACBA is identical to the SBA carrier) or fabrication is not clear. In any event the carrier fit the body poorly and the plate contour poorly. Reference 8 indicated little development effort was expended on this carrier for the ACBA system provided. Nevertheless, carrier design is critical to system usefulness for the following reasons:

a. Maintains plate position on the body.

b. Distributes plate weight on the body surface.

c. Interacts with the seat back, survival vest and seat restraint system.

The following problems were directly associated with the carrier:

a. Shoulder Pads

Pad(s) width too wide causing chafing at each side of the neck.

Pads(s) placement in relation to plate carrier portion is poor, pad(s) tend to rotate inward.

Maintenance of shoulder pad(s) position on the shoulder is ineffective - pad(s) move out from under the shoulder straps under normal movement.

Attachment straps are too narrow - they do not always lie flat nor do they distribute the plate load effectively over the pad surface.

b. Neck Cut-Out

Diameter too small, irrespective of carrier size - contacts the side of the wearers neck.

Front configuration of cut-out causes pressure in the area of the sternal notch.

c. Upper Torso

Material seam around the armor plate binds in upper arm/shoulder area and produces a pressure point.

Adjustment straps do not provide sufficient adjustment to hold plate so it provides effective upper chest coverage nor, do they maintain the plate in a consistent position.

Strap attachment to the plate carrier portion allows plate standoff around the lung area, and results in binding at the waist.

d. Lower Torso

Side elastic pieces (left/right) serve no useful purpose - they tend to allow the plate to shift left or right depending on which side is more tightly adjusted.

Closure flap(s) contact area should be increased in width to allow wrapping at the lowest possible position which would improve maintenance of plate position.

Finger loop/snap fastener appendage is usually too long or too short for the closure to be fastened. Its use for quick removal of the closure flaps is questionable - a simple loop on the end of the top closure flap would serve the same purpose.

e. Carrier Back

In all sizes the back material rides up, bunches and binds around the base of the neck (rear) and bunches up in small of back area. The carrier back was designed to be used with a back armored plate, counter-balancing the front plate weight. For use with only a front plate, the back carrier should be cut longer and contain no extra pocket. The longer cut would provide a perpendicular plane with the bottom of the carrier front to facilitate closure effectiveness and, more importantly, plate position maintenance.

Plate: In all sizes plate fit was significantly degraded by carrier deficiencies. It becomes apparent when using these plates in a seated position that they were designed to be used in an erect position. The predominant operational use of these plates is from a seated position. Classically this position is characterized by a forward slump of the upper torso. For both reasons of comfort and to facilitate air vehicle control the right forearm (cyclic control) is rested upon the upper portion of the right thigh. As a result of this characteristic forward slump the long plate lengths (on center-line) seriously restrict and cause discomfort to the operator. In addition, the plates are forced upward and constitute a safety hazard by being forced into the throat/jaw area. However, the plates provided with the anatomically configured aircrew armor can be improved through minor configuration and dimensional changes (See Recommendations Section).

a. Too wide at chest- contributes significantly to deltoid and biceps binding.

b. Peripheral shoulder protection wings proximity to the throat and jaw is dangerously close, in all cases subjects could contact wings with chin, jaw and throat without excessive head movement forward. This could contribute significantly to chin, jaw, throat injuries during mild forward accelerations.

c. In all sizes plate center-line length is excessive.

d. Plate weight, both Al_2O_3 and B_4C plates were used in the assessment - the average weight difference between the two types was 32 ounces. The only apparent advantage to changing material in the current standard plate (Al_2O_3) to B_4C would be a decrease in sag. However, carrier improvement and plate reconfiguration would in all likelihood also improve the sag characteristic.

Miscellaneous

a. Spall Protection - The anatomical armor provides full felt type spall protection.

b. Doffing/Donning - The system requires two separate and distinct sets of movements to remove or jettison and is accomplished as follows:

(1) Unsnap shoulder fasteners using pull tab.

(2) Unwrap waist closure by separating velcro material using the pull tab.

The snap fasteners are difficult to engage.

Quick releases on one side (snap fasteners - two each) do not readily release. On the other side, no release is provided.

Velcro waist fastener on the right side does not always disengage with one quick pull from right to left, thus leaving the far right portion still attached to the individual. Excessive arm swing outward and to the right is required to insure complete disengagement.

RECOMMENDATIONS FOR THE ACBA SYSTEM

The recommendations presented for the ACBA are extensive for the carrier and very minor for the plate. As previously stated these modifications will result in an exceptionally compatible body armor system for aircrewmen.

Carrier - All Sizes

a. Shoulder pad dimension - decrease and locate farther out on the shoulders.

b. Shoulder strap width increase.

c. Shoulder strap attachment and release system redesigned..

d. Neck cut-out diameter increased.

e. Additional adjustment capability for the shoulder straps.

f. Strap attachment to the armor plate carrier portion relocated behind the plate.

g. Side elastic straps eliminated.

h. Closure flap surface area increased.

i. Finger loop-snap fastener removed and loop made integral with closure flap.

j. Carrier back for pilot/copilot use should be cut longer and contain no excess material.

k. Carrier back material be of open weave or net type material to improve evaporative cooling.

l. Study the possibility of carrier becoming part of survival vest.

Plate - All Sizes

a. Remove upper armor wings.

b. Reduction of plate width between the deltoids by .5 inch.

c. Provide padding on top portion of armor plate.

d. Provide padding around lower edge of armor plate.

e. Eliminate rubber edge material from armor plate periphery.

f. Reduce plate length by 1.5 inches across entire bottom edge contour but retain the flaring.

CONCLUSIONS FOR THE SBA SYSTEM

Carrier: The carrier provided with the standard aircrew armor can be improved considerably. The following problems have been noted:

a. Shoulder Pads

Pad(s) width too wide.

Pad(s) placement in relation to plate carrier portion is poor, pad(s) tend to rotate inward.

Maintainence of shoulder pad(s) position on the shoulder is ineffective - pad(s) move out from under the shoulder straps under normal movement.

Attachment straps are too narrow - they do not always lie flat nor do they distribute the plate load effectively over the pad surface.

b. Neck Cut-Out

Diameter too small, irrespective of carrier size - contacts the side of the weares neck.

Front configuration of cut-out contacts the base of the neck (front).

c. Upper Torso

Material seam around the armor plate binds in upper arm/shoulder area and produces a pressure point.

Adjustment straps do not provide sufficient adjustment to hold plate so it provides effective upper chest coverage,nor do they hold the plate in a confortable position.

Strap attachment to the plate carrier portion allows plate standoff around the lung area.

d. Lower Torso

Side elastic pieces (left/right) serve no useful purpose - they tend to allow the plate to shift left or right depending on which side is pulled up tightest.

Closure flap(s) contact area should be increased in width to allow wrapping at the lowest possible position which would improve maintenance of plate position.

Finger loop/snap fastener appendage is usually too long or too short to be fastened. Its use for quick removal of the closure flaps is questionable - a simple loop on the end of the top closure flap would serve the same purpose.

e. Carrier Back

In all sizes the back material rides up, bunches and binds around the base of the neck (rear) and bunches up in small of back area. The carrier back was designed to be used with a back armored plate, counter-balancing the front plate weight. For use with only a front plate, the back carrier should be cut longer and contain no extra pocket. The longer cut would provide a perpendicular plane with the bottom of the carrier front to facilitate closure effectiveness and, more importantly, plate position maintenance.

Plate: The plate provided with the standard aircrew armor can be improved radically through configuration (curvature) change.

a. Too wide at chest - contributes significantly to deltoid and biceps binding.

Lack of contouring in the area around the sternum results in a pressure point on the sternal bone and also contributes to binding at the arm/shoulder juncture.

Upper wing tips proximity to the throat and jaw is dangerously close in all cases subjects could contact wings with chin, jaw and throat without excessive head movement forward. This could contribute significantly to chin, jaw, throat injuries during mild forward accelerations.

Breadth at waist wings is excessive and increases operator effective waist breadth significantly. This dimension has significant impact on crew station design, i.e., seat width and seat armor plate width, and operator mobility.

Lack of contouring at the waist and waist wings contributes to the comment above and also reduces effective waist protection in the waist area by stand-off from the body.

Plate lower wing interferes with side mobility, by contacting iliac crest or thigh top.

Plate lower lip lacks contouring, therefore, plate binds and applies pressure to the thigh top and groin area.

Plate Weight - Both Al_2O_3 and B_4C plates were used in the assessment - the average weight difference between the two types was 32 ounces. The only apparent advantage to changing material in the current standard plate (Al_2O_3) to B_4C would be a decrease in sag. However, carrier improvement and plate reconfiguration would in all likelihood also improve the sag variable.

Miscellaneous

a. Spall Protection

The standard armor provides very little spall protection. Current RVN practice is to wear the M1952 Fragmentation Protective Vest over the armor plate. This combination with the addition of a survival vest appears incompatible with the majority of Army aircraft aircrew stations due to increase in basic body dimensions, i.e., shoulder breadth, waist breadth, chest depth, and stomach depth. Some sort of spall protection should be built into the carrier body. The additional weight increase associated with using the plate/carrier and fragment vest strongly suggests a need for designing a carrier with built-in spall protection.

b. Doffing/Donning

The system requires two separate and distinct sets of movements to remove or jettison and is accomplished as follows:

(1) Unsnap shoulder fasteners using pull tab.

(2) Unsnap waist closure by separating velcro material using the pull tab.

Snap fasteners are difficult to engage.

Quick release on one side (snap fasteners - two each) donot always readily release. On the other side, no release is provided.

Velcro waist fastener on the right side does not always disengage with one quick pull from right to left, thus leaving the far right portion still attached to the individual. Excessive arm swing outward and to the right is required to insure complete disengagement.

RECOMMENDATIONS FOR THE SBA SYSTEM

Carrier - All Sizes

a. Shoulder pad dimension - decrease and locate farther out on the shoulder.

b. Shoulder strap width increase.

c. Shoulder strap attachment and release system redesigned.

d. Neck cut-out diameter increased.

e. Additional adjustment capability for the shoulder straps.

f. Strap attachment to the armor plate carrier portion relocated behind the plate.

g. Side elastic straps eliminated.

h. Closure flap surface area increased.

i. Finger loop/snap fastener removed and loop made integral with closure flap.

j. Carrier back for pilot/copilot use should be cut longer and contain no excess material.

k. Carrier back material be of open weave or net type material to improve evaporative cooling.

l. Spall protection build into portion containing armor plate.

m. Study the possibility of carrier becoming part of survival vest.

Plate - All Sizes

a. Remove upper armor wings.

b. Contour upper chest section.

c. Reduce upper chest section width.

d. Provide padding on top portion of armor plate.

e. Contour waist section and wings to conform to body shape for respective sizes.

f. Provide padding around lower edge of armor plate.

g. Eliminate rubber edge material from armor plate periphery.

h. Flair lower edge of plate outward to help eliminate thigh and groin pressure.

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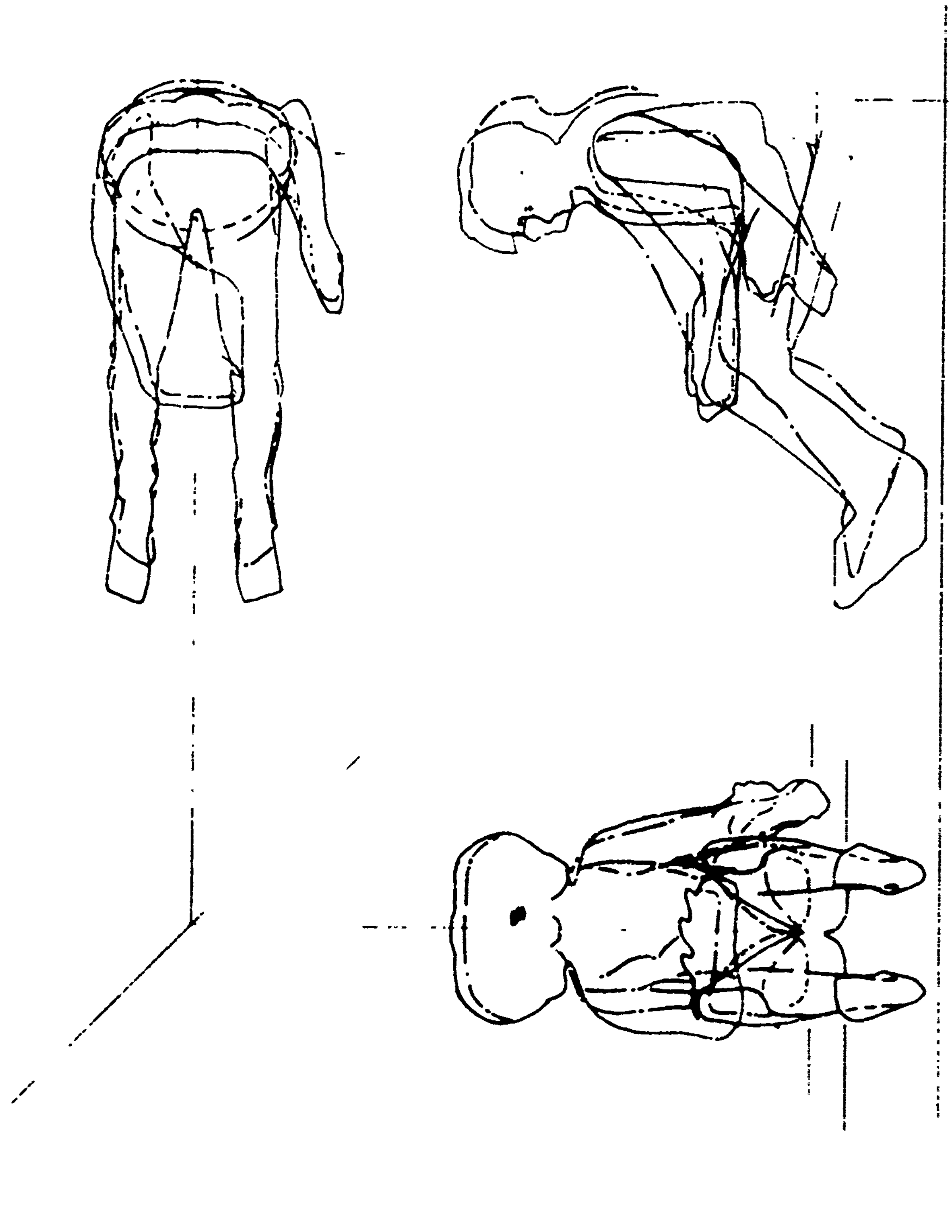
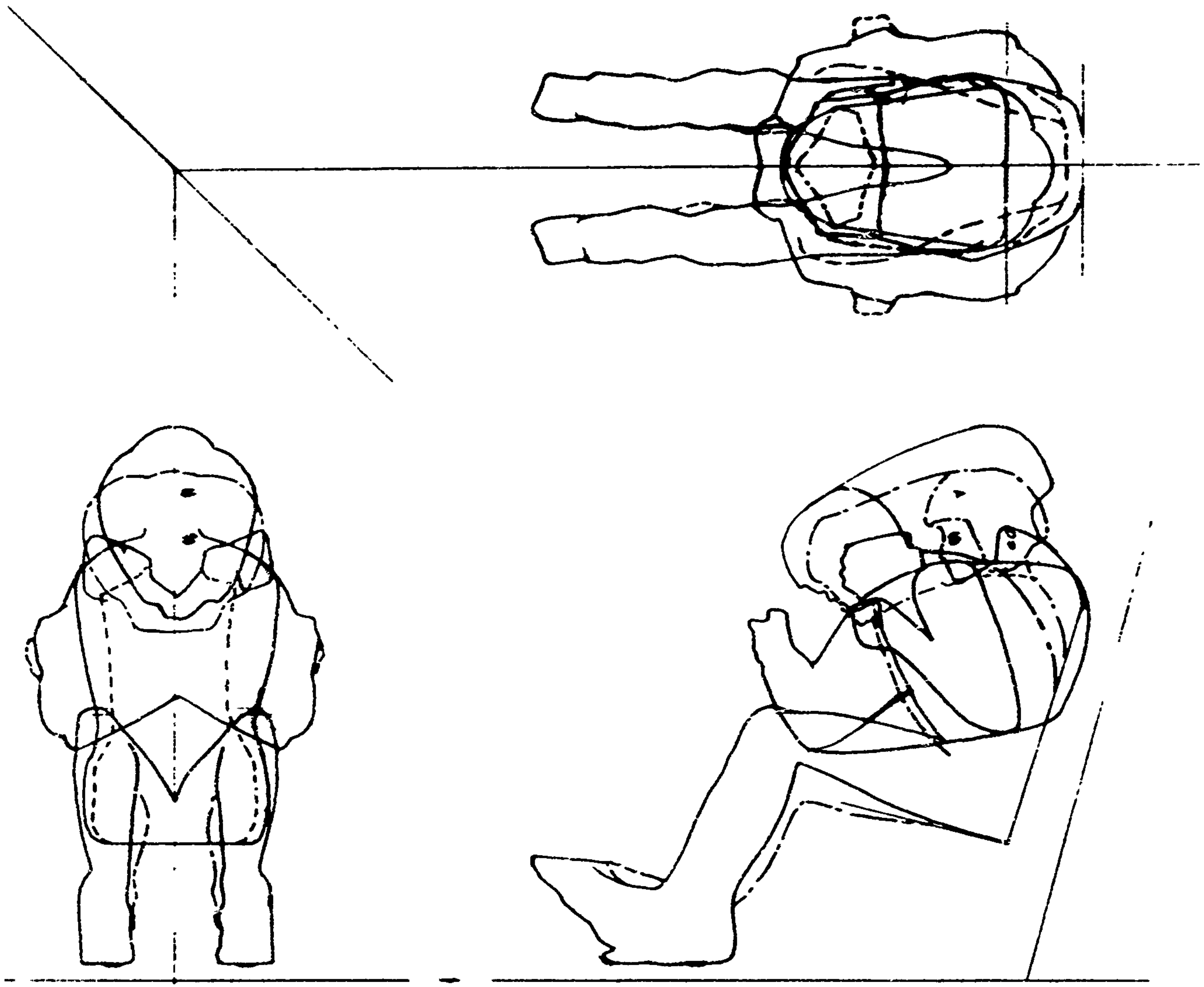
APPENDIX A

PILOT AND COPILOT MOTION ENVELOPES AH-1G



PILOT MOTION ENVELOPE AH-1G



COPILOT MOTION ENVELOPE AH-1G

APPENDIX B

PROTECTION NEED MATRIX FOR AH-1G ATTACK HELICOPTER

The azimuth and elevation values are determined with respect to the helicopters reference plane. The crew motion envelope manikins did not separate thorax and abdomin via a color change. It was necessary to estimate whether or not a shot could strike these regions.

AIRCRAFT AH-1G

CREWMEMBER COPILOT

DIRECTION OF FIRE		BODY PART						
EL.	AZ.	HEAD	THORAX	ABDOMEN	RIGHT LEG	LEFT LEG	RIGHT ARM	LEFT ARM
	0°	38.4	0	0	3.4	3.4	0.5	0.5
	22.5	38.4	0	0	3.4	3.4	0.5	0.5
	45	38.4	40.5	0	3.4	3.4	0.5	0.5
	67.5	38.4	40.5	0	3.4	3.4	0.5	0.5
	90	38.4	40.5	0	3.4	3.4	0.5	0.5
	112.5	38.4	40.5	0	3.4	3.4	0.5	0.5
	135	38.4	40.5	0	3.4	3.4	0.5	0
	157.5	38.4	40.5	0	3.4	3.4	0.5	0.5
+67.5°	180	38.4	40.5	0	3.4	3.4	0.5	0.5
	202.5	38.4	40.5	0	3.4	3.4	0.5	0.5
	225	38.4	40.5	0	3.4	3.4	0.5	0.5
	247.5	38.4	40.5	0	3.4	3.4	0.5	0.5
	270	38.4	40.5	0	3.4	3.4	0.5	0.5
	292.5	38.4	40.5	0	3.4	3.4	0.5	0.5
	315	38.4	40.5	0	3.4	3.4	0.5	0.5
	337.5	38.4	40.5	0	3.4	3.4	0.5	0.5

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AIRCRAFT AH-1G

CREWMEMBER PILOT

DIRECTION OF FIRE		BODY PART						
EL.	AZ.	HEAD	THORAX	ABDOMEN	RIGHT LEG	LEFT LEG	RIGHT ARM	LEFT ARM
	0°	38.4	40.5	42.4	3.4	3.4	0.5	0.5
	22.5	38.4	40.5	42.4	3.4	3.4	0.5	0.5
	45	38.4	40.5	0	3.4	3.4	0.5	0.5
	67.5	38.4	40.5	0	3.4	3.4	0.5	0.5
	90	38.4	40.5	0	3.4	3.4	0.5	0.5
	112.5	38.4	40.5	0	3.4	3.4	0.5	0.5
	135	38.4	40.5	0	3.4	3.4	0.5	0
+67.5°	157.5	38.4	40.5	0	3.4	3.4	0.5	0.5
	180	38.4	40.5	0	3.4	3.4	0.5	0.5
	202.5	38.4	40.5	0	3.4	3.4	0.5	0.5
	225	38.4	40.5	0	3.4	3.4	0.5	0.5
	247.5	38.4	40.5	0	3.4	3.4	0.5	0.5
	270	38.4	40.5	42.4	3.4	3.4	0.5	0.5
	292.5	38.4	40.5	42.4	3.4	3.4	0.5	0.5
	315	38.4	40.5	42.4	3.4	3.4	0.5	0.5
	337.5	38.4	40.5	42.4	3.4	3.4	0.5	0.5

AIRCRAFT AH-1G

CREWMEMBER COPILOT

DIRECTION OF FIRE		BODY PART						
EL.	AZ.	HEAD	THORAX	ABDOMEN	RIGHT LEG	LEFT LEG	RIGHT ARM	LEFT ARM
+45°	0°	38.4	0	0	3.4	3.4	0.5	0.5
	22.5	38.4	40.5	0	3.4	3.4	0.5	0.5
	45	38.4	40.5	0	3.4	3.4	0.5	0.5
	67.5	38.4	40.5	0	3.4	3.4	0.5	0.5
	90	38.4	40.5	0	3.4	3.4	0.5	0
	112.5	38.4	40.5	0	3.4	3.4	0.5	0
	135	38.4	40.5	0	3.4	3.4	0.5	0.5
	157.5	38.4	40.5	0	3.4	0	0.5	0.5
	180	38.4	40.5	0	3.4	0	0.5	0.5
	202.5	38.4	40.5	0	0	3.4	0.5	0.5
	225	38.4	40.5	0	3.4	3.4	0	0.5
	247.5	38.4	40.5	0	3.4	3.4	0	0.5
	270	38.4	40.5	0	3.4	3.4	0	0.5
	292.5	38.4	40.5	0	3.4	3.4	0.5	0.5
	315	38.4	40.5	0	3.4	3.4	0.5	0.5
	337.5	38.4	0	0	3.4	3.4	0.5	0.5

AIRCRAFT AH-1G

CREWMEMBER PILOT

DIRECTION OF FIRE		BODY PART						
EL.	AZ.	HEAD	THORAX	ABDOMEN	RIGHT LEG	LEFT LEG	RIGHT ARM	LEFT ARM
+45°	0°	38.4	40.5	42.4	3.4	3.4	0.5	0.5
	22.5	38.4	40.5	42.4	3.4	3.4	0.5	0.5
	45	38.4	40.5	42.4	3.4	3.4	0.5	0.5
	67.5	38.4	40.5	0	3.4	3.4	0.5	0.5
	90	38.4	40.5	0	3.4	3.4	0.5	0
	112.5	38.4	40.5	0	3.4	3.4	0.5	0.5
	135	38.4	40.5	0	3.4	3.4	0.5	0.5
	157.5	38.4	40.5	0	3.4	0	0.5	0.5
	180	38.4	40.5	0	3.4	0	0.5	0.5
	202.5	38.4	40.5	0	0	3.4	0.5	0.5
	225	38.4	40.5	0	3.4	3.4	0.5	0.5
	247.5	38.4	40.5	0	3.4	3.4	0.5	0.5
	270	38.4	40.5	0	3.4	3.4	0.5	0.5
	292.5	38.4	40.5	42.4	3.4	3.4	0.5	0.5
	315	38.4	40.5	42.4	3.4	3.4	0.5	0.5
	337.5	38.4	40.5	42.4	3.4	3.4	0.5	0.5

AIRCRAFT AH-1G

CREWMEMBER COPILOT

DIRECTION OF FIRE		BODY PART						
EL.	AZ.	HEAD	THORAX	ABDOMEN	RIGHT LEG	LEFT LEG	RIGHT ARM	LEFT ARM
+22.5°	0°	38.4	40.5	0	3.4	3.4	0.5	0.5
	22.5	38.4	40.5	0	3.4	3.4	0.5	0.5
	45	38.4	40.5	0	3.4	3.4	0.5	0.5
	67.5	38.4	40.5	0	3.4	3.4	0.5	0.5
	90	38.4	40.5	0	3.4	3.4	0.5	0
	112.5	38.4	40.5	0	3.4	3.4	0.5	0
	135	38.4	40.5	0	3.4	0	0.5	0.5
	157.5	38.4	40.5	0	3.4	0	0.5	0.5
	180	38.4	0	0	0	0	0.5	0
	202.5	38.4	40.5	0	0	3.4	0	0.5
	225	38.4	40.5	0	3.4	3.4	0	0.5
	247.5	38.4	40.5	0	3.4	3.4	0	0.5
	270	38.4	40.5	0	3.4	3.4	0.5	0.5
	292.5	38.4	40.5	0	3.4	3.4	0.5	0.5
	315	38.4	40.5	0	3.4	3.4	0.5	0.5
	337.5	38.4	40.5	0	3.4	3.4	0.5	0.5

AIRCRAFT AH-1G

CREWMEMBER PILOT

DIRECTION OF FIRE		BODY PART						
EL.	AZ.	HEAD	THORAX	ABDOMEN	RIGHT LEG	LEFT LEG	RIGHT ARM	LEFT ARM
+22.5°	0°	38.4	40.5	0	3.4	3.4	0.5	0.5
	22.5	38.4	40.5	42.4	3.4	3.4	0.5	0.5
	45	38.4	40.5	42.4	3.4	3.4	0.5	0.5
	67.5	38.4	40.5	0	3.4	3.4	0.5	0
	90	38.4	40.5	0	3.4	3.4	0.5	0
	112.5	38.4	40.5	0	3.4	0	0.5	0
	135	38.4	40.5	0	3.4	0	0.5	0.5
	157.5	38.4	40.5	0	3.4	0	0.5	0.5
	180	38.4	40.5	0	0	3.4	0.5	0.5
	202.5	38.4	40.5	0	0	3.4	0.5	0.5
	225	38.4	40.5	0	3.4	3.4	0.5	0.5
	247.5	38.4	40.5	0	3.4	3.4	0.5	0.5
	270	38.4	40.5	0	3.4	3.4	0.5	0.5
	292.5	38.4	40.5	42.4	3.4	3.4	0.5	0.5
	315	38.4	40.5	42.4	3.4	3.4	0.5	0.5
	337.5	38.4	40.5	42.4	0	3.4	0.5	0.5

AIRCRAFT AH-1G

CREWMEMBER COPILOT

DIRECTION OF FIRE		BODY PART						
EL.	AZ.	HEAD	THORAX	ABDOMEN	RIGHT LEG	LEFT LEG	RIGHT ARM	LEFT ARM
0°	0°	38.4	0	0	3.4	3.4	0.5	0.5
	22.5	38.4	0	0	3.4	3.4	0.5	0.5
	45	38.4	0	0	3.4	3.4	0.5	0.5
	67.5	38.4	0	0	3.4	3.4	0.5	0
	90	38.4	0	0	3.4	0	0.5	0
	112.5	38.4	0	0	3.4	3.4	0.5	0
	135	38.4	0	0	3.4	3.4	0.5	0.5
	157.5	38.4	0	42.4	3.4	0	0.5	0.5
	180	0	0	0	0	0	0	0
	202.5	38.4	0	0	0	3.4	0	0.5
	225	38.4	40.5	42.4	3.4	3.4	0	0.5
	247.5	38.4	0	0	3.4	3.4	0	0.5
	270	38.4	0	0	3.4	3.4	0	0.5
	292.5	38.4	0	0	3.4	3.4	0	0.5
	315	38.4	0	0	3.4	3.4	0.5	0.5
	337.5	38.4	0	0	3.4	3.4	0.5	0.5

AIRCRAFT AH-1G

CREWMEMBER PILOT

DIRECTION OF FIRE		BODY PART						
EL.	AZ.	HEAD	THORAX	ABDOMEN	RIGHT LEG	LEFT LEG	RIGHT ARM	LEFT ARM
	0°	38.4	0	0	0	0	0.5	0.5
	22.5	38.4	40.5	42.4	3.4	3.4	0.5	0.5
	45	38.4	40.5	42.4	3.4	3.4	0.5	0.5
	67.5	38.4	40.5	42.4	3.4	3.4	0.5	0
	90	38.4	40.5	42.4	3.4	0	0.5	0
	112.5	38.4	40.5	42.4	3.4	3.4	0.5	0
	135	38.4	40.5	42.4	3.4	3.4	0.5	0.5
	157.5	38.4	40.5	42.4	3.4	3.4	0.5	0.5
0°	180	38.4	0	0	0	0	0.5	0.5
	202.5	38.4	40.5	0	3.4	3.4	0	0.5
	225	38.4	40.5	0	3.4	3.4	0	0.5
	247.5	38.4	40.5	0	3.4	3.4	0.5	0.5
	270	38.4	40.5	0	0	3.4	0.5	0.5
	292.5	38.4	40.5	0	3.4	3.4	0.5	0.5
	315	38.4	40.5	0	3.4	3.4	0.5	0.5
	337.5	38.4	40.5		3.4	3.4	0	0.5

AIRCRAFT AH-1G

CREWMEMBER COPILOT

DIRECTION OF FIRE		BODY PART						
EL.	AZ.	HEAD	THORAX	ABDOMEN	RIGHT LEG	LEFT LEG	RIGHT ARM	LEFT ARM
	0°	38.4	0	42.4	3.4	3.4	0.5	0.5
	22.5	38.4	0	0	3.4	3.4	0.5	0
	45	38.4	0	0	3.4	3.4	0.5	0
	67.5	38.4	0	0	3.4	3.4	0.5	0
	90	38.4	0	0	3.4	3.4	0.5	0
	112.5	38.4	0	0	3.4	3.4	0.5	0
	135	38.4	0	0	3.4	3.4	0.5	0
	157.5	38.4	0	0	3.4	0	0.5	0
-22.5°	180	0	0	0	0	0	0.5	0
	202.5	0	0	0	0	3.4	0.5	0
	225	38.4	40.5	0	3.4	3.4	0	0
	247.5	38.4	40.5	0	3.4	3.4	0.5	0
	270	38.4	0	0	3.4	3.4	0.5	0
	292.5	38.4	0	0	3.4	3.4	0.5	0
	315	38.4	0	0	3.4	3.4	0.5	0
	337.5	38.4	0	0	3.4	3.4	0	0.5

AIRCRAFT AH-1G

CREWMEMBER PILOT

DIRECTION OF FIRE		BODY PART						
EL.	AZ.	HEAD	THORAX	ABDOMEN	RIGHT LEG	LEFT LEG	RIGHT ARM	LEFT ARM
	0°	0	0	0	0	0	0	0.5
	22.5	38.4	40.5	0	3.4	0	0.5	0
	45	38.4	40.5	0	3.4	3.4	0.5	0
	67.5	38.4	40.5	42.4	3.4	3.4	0.5	0.5
	90	38.4	0	42.4	3.4	3.4	0.5	0
	112.5	38.4	0	42.4	3.4	3.4	0.5	0
	135	38.4	0	0	3.4	3.4	0.5	0
	157.5	38.4	0	0	3.4	3.4	0.5	0.5
-22.5°	180	38.4	0	0	3.4	3.4	0.5	0.5
	202.5	38.4	0	0	3.4	3.4	0	0.5
	225	38.4	0	0	3.4	3.4	0	0.5
	247.5	38.4	0	0	3.4	3.4	0	0.5
	270	38.4	0	0	3.4	3.4	0.5	0.5
	292.5	38.4	40.5	0	3.4	3.4	0.5	0.5
	315	38.4	40.5	0	3.4	3.4	0.5	0.5
	337.5	38.4	40.5	0	3.4	3.4	0	0.5

AIRCRAFT AH-1G

CREWMEMBER COPILOT

DIRECTION OF FIRE		BODY PART						
EL.	AZ.	HEAD	THORAX	ABDOMEN	RIGHT LEG	LEFT LEG	RIGHT ARM	LEFT ARM
-45°	0°	38.4	40.5	0	3.4	3.4	0.5	0.5
	22.5	38.4	0	0	3.4	3.4	0.5	0
	45	38.4	0	0	3.4	3.4	0.5	0
	67.5	38.4	0	0	3.4	3.4	0.5	0
	90	38.4	0	0	3.4	3.4	0.5	0
	112.5	38.4	0	0	3.4	3.4	0.5	0
	135	38.4	0	0	3.4	0	0.5	0
	157.5	0	0	0	3.4	0	0.5	0
	180	0	0	0	0	0	0.5	0
	202.5	0	0	0	0	3.4	0	0.5
	225	38.4	0	0	0	3.4	0	0.5
	247.5	38.4	0	0	0	3.4	0	0.5
	270	38.4	0	0	3.4	3.4	0	0.5
	292.5	38.4	0	0	3.4	3.4	0	0.5
	315	38.4	0	0	3.4	3.4	0	0.5
	337.5	38.4	0	0	3.4	3.4	0	0.5

AIRCRAFT AH-1G

CREWMEMBER PILOT

DIRECTION OF FIRE		BODY PART						
EL.	AZ.	HEAD	THORAX	ABDOMEN	RIGHT LEG	LEFT LEG	RIGHT ARM	LEFT ARM
-45°	0°	38.4	0	0	0	0	0	0.5
	22.5	38.4	0	0	3.4	0	0.5	0
	45	38.4	0	0	3.4	0	0.5	0
	67.5	38.4	0	0	3.4	0	0.5	0
	90	38.4	0	0	3.4	3.4	0.5	0.5
	112.5	38.4	0	42.4	3.4	3.4	0.5	0.5
	135	0	0	0	3.4	3.4	0.5	0
	157.5	38.4	0	0	3.4	3.4	0.5	0
	180	0	0	0	3.4	3.4	0.5	0.5
	202.5	38.4	0	0	3.4	3.4	0	0.5
	225	0	0	0	3.4	3.4	0	0.5
	247.5	38.4	0	0	3.4	3.4	0.5	0.5
	270	38.4	0	0	3.4	3.4	0.5	0.5
	292.5	38.4	40.5	0	3.4	3.4	0.5	0
	315	38.4	40.5	0	3.4	3.4	0.5	0
	337.5	38.4	0	0	3.4	3.4	0.5	0

AIRCRAFT AH-1G

CREWMEMBER COPILOT

DIRECTION OF FIRE		BODY PART						
EL.	AZ.	HEAD	THORAX	ABDOMEN	RIGHT LEG	LEFT LEG	RIGHT ARM	LEFT ARM
-67.5°	0°	38.4	0	0	3.4	3.4	0	0.5
	22.5	0	0	0	3.4	3.4	0.5	0.5
	45	38.4	0	0	3.4	3.4	0.5	0
	67.5	38.4	0	0	3.4	3.4	0.5	0
	90	38.4	0	0	3.4	3.4	0.5	0
	112.5	38.4	0	0	3.4	3.4	0.5	0
	135	0	0	0	3.4	0	0.5	0
	157.5	0	0	0	3.4	0	0.5	0
	180	0	0	0	0	0	0	0
	202.5	38.4	0	0	3.4	0	0	0.5
	225	38.4	0	0	0	3.4	0	0.5
	247.5	0	0	0	3.4	3.4	0	0.5
	270	38.4	0	0	3.4	3.4	0	0.5
	292.5	38.4	0	0	3.4	3.4	0	0.5
	315	38.4	0	0	3.4	3.4	0	0.5
	337.5	38.4	0	0	3.4	3.4	0	0.5

AIRCRAFT AH-1G

CREWMEMBER PILOT

DIRECTION OF FIRE		BODY PART						
EL.	AZ.	HEAD	THORAX	ABDOMEN	RIGHT LEG	LEFT LEG	RIGHT ARM	LEFT ARM
-67.5°	0°	38.4	0	0	0	0	0	0.5
	22.5	38.4	0	0	0	0	0.5	0
	45	38.4	0	0	0	0	0.5	0
	67.5	38.4	0	0	3.4	0	0.5	0
	90	38.4	0	0	3.4	0	0.5	0
	112.5	0	0	0	3.4	3.4	0.5	0.5
	135	0	0	0	3.4	3.4	0.5	0.5
	157.5	0	0	0	3.4	3.4	0.5	0.5
	180	0	0	0	3.4	3.4	0.5	0.5
	202.5	38.4	0	0	3.4	0	0	0.5
	225	38.4	0	0	3.4	3.4	0	0.5
	247.5	0	0	0	0	3.4	0	0.5
	270	0	0	0	0	3.4	0	0.5
	292.5	38.4	0	0	0	3.4	0	0.5
	315	38.4	0	0	0	3.4	0	0.5
	337.5	38.4	0	0	0	3.4	0	0.5

AIRCRAFT AH-1G

CREWMEMBER COPILOT

DIRECTION OF FIRE		BODY PART						
EL.	AZ.	HEAD	THORAX	ABDOMEN	RIGHT LEG	LEFT LEG	RIGHT ARM	LEFT ARM
+90°	0°	38.4	40.5	0	3.4	3.4	0.5	0.5
	22.5							
	45							
	67.5							
	90							
	112.5							
	135							
	157.5							
	180							
	202.5							
	225							
	247.5							
	270							
	292.5							
	315							
	337.5							

AIRCRAFT AH-1G

CREWMEMBER COPILOT

DIRECTION OF FIRE		BODY PART						
EL.	AZ.	HEAD	THORAX	ABDOMEN	RIGHT LEG	LEFT LEG	RIGHT ARM	LEFT ARM
-90°	0°	0	0	0	3.4	3.4	0.5	0.5
	22.5							
	45							
	67.5							
	90							
	112.5							
	135							
	157.5							
	180							
	202.5							
	225							
	247.5							
	270							
	292.5							
	315							
	337.5							

AIRCRAFT AH-1G

CREWMEMBER PILOT

DIRECTION OF FIRE		BODY PART						
EL.	AZ.	HEAD	THORAX	ABDOMEN	RIGHT LEG	LEFT LEG	RIGHT ARM	LEFT ARM
-90°	0°	0	0	0	0	0	0.5	0.5
	22.5							
	45							
	67.5							
	90							
	112.5							
	135							
	157.5							
	180							
	202.5							
	225							
	247.5							
	270							
	292.5							
	315							
	337.5							

AIRCRAFT AH-1G

CREWMEMBER PILOT

DIRECTION OF FIRE		BODY PART						
EL.	AZ.	HEAD	THORAX	ABDOMEN	RIGHT LEG	LEFT LEG	RIGHT ARM	LEFT ARM
	0°	38.4	40.5	0	3.4	3.4	0.5	0.5
	22.5							
	45							
	67.5							
	90							
	112.5							
	135							
	157.5							
+90°	180							
	202.5							
	225							
	247.5							
	270							
	292.5							
	315							
	337.5							

APPENDIX C

SAMPLE ANTHROPOMETRIC DATA SHEET

DATE ______________	BIRTH DATE: Mo. 5 Day 14 Yr. 45
SUBJECT NO. 15	AGE : 25 Yrs. 4 Mos.

	Shorts	Fatigues	Standard Armor		Anatomic Armor	
			F size LG	size	F size M-L	size Pref. L-R
1. Weight (Lbs.)	202	210				
2. Height (Inches)	74	75				
3. Sitting Height (1/10 In.)	38.6					
4. Shoulder Height (1/10 In.)	26.9					
5. Shoulder Breadth (1/10 In.)	20.3	20.2	20.4		20.4	20.5
6. Buttock-Knee Length (1/10 In.)	25.6	26.2				
7. Leg Length (1/10 In.)	45.5	47.3				
8. Chest Depth (Inches)	10.8		11		11.8	11.8
9. Stomach Depth (Inches)	10.3		12		12.3	11.8
10. Arm Reach (Inches)	36.5	36.5	36.5		38.5	38
11. Stomach Circumference (Inches)	38	40	44.3		45	45
12. Chest Circumference (Inches)	40	39.5	42.3		43.8	43.8
13. Waist Front (Inches)	16					
14. Chest Breadth (Cm.)	32.2 32.0	31.8 31.6				
15. Waist Breadth (Cm.)	32.7 32.5	32.4 32.2	42.8 42.6		37.1 36.9	38.5 38.3
16. Hip Breadth (Cm.)	39.3 39.1	35.9 35.7	38.8 38.6		40.4 40.2	37.0 36.8
17. Eye Height (Cm.)	85.5 84.1					
18. Thigh Top-Seat Surface (Cm.)	17.8 16.4	18.7 17.3				
19. Sternal Notch-Seat Surf.(Cm.)	62.7 61.3					
20. Scye-Seat Surface (Cm.)	49.6 48.2	48.2 46.9				
21. Plate-Seat Surface (Cm.)			60.3 58.9		59.7 58.3	57.5 56.1
22. Plate Hg. Pt. - Seat Surf. (Cm.)			63.1 61.7		61.8 60.4	59.2 57.8
23. Sternal Notch-Mandible (Cm.)	12.9					
24. Head Height (Cm.)	21.6 21.1					

Neck Circumference (In.) 15 1/2

Neck Breadth (Cm.) 12.6

Prefers Anatomical Over Standard

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